SOIL STABILIZATION

INVESTIGATIONS OF QUICKLIME AS A STABILIZING MATERIAL

TECHNICAL REPORT NO. 3-455

Report 5

March 1962

U. S. Army Engineer Waterways Experiment Station
CORPS OF ENGINEERS
Vicksburg, Mississippi

U. S. Army Engineer Waterways Experiment Station, CE, Vicksburg, Miss. SOIL STABILIZATION; INVESTIGATIONS OF QUICKLIME AS A STABILIZING MATERIAL, by G. R. Kozan and W. B. Fenwick. March 1962, vii, 47 pp - illus - tables. (Technical Report No. 3-455, Report 5)

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PREFACE

The investigation reported herein was conducted for the Office, Chief of Engineers, under the authority of the soil stabilization program of Research and Development Project 8S70-05-001, "Trafficability and Mobility Research," Task -05, "Mobility Engineering Support." This work was conducted formerly under Subproject 8-70-03-520, "Solidifying or Stabilizing Soils for Military Operations."

This report describes laboratory and field investigations of quicklime as a soil-stabilizing material for construction of emergency military roads and airfields conducted at the U. S. Army Engineer Waterways Experiment Station during the period March to October 1959.

The study was performed by Messrs. D. R. Freitag, formerly Chief of the Soils Stabilization Section, G. R. Kozan, and J. D. Stouffer, under the general direction of Messrs. W. J. Turnbull and W. G. Shockley, Soils Division. Laboratory work was supervised by Mr. J. E. Mitchell, and the field test operations were supervised by Mr. B. G. Schreiner. This report was prepared by Messrs. G. R. Kozan and W. B. Fenwick.

Col. Edmund H. Lang, CE, and Col. Alex G. Sutton, Jr., CE, were Directors of the Waterways Experiment Station during the conduct of the investigation and the preparation and publication of this report. Mr. J. B. Tiffany was Technical Director.

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SUMMARY

The military needs a material capable of stabilizing weak soils sufficiently to support traffic for specific emergency operations. Based on encouraging results of earlier work with quicklime in stabilization of extremely wet and untrafficable soils, a laboratory and field investigation was conducted to determine its potential in the stabilization of soils of moderate initial water content and stability.

Preliminary laboratory tests showed that as little as 4% quicklime by soil weight was capable of increasing the unconfined compressive strength of a lean clay soil (Vicksburg loess) from an initial 20 psi to over 100 psi, and its bearing capacity from a CBR of 4 to over 50 within 24 hr after treatment, thus exceeding the minimum laboratory strength criteria established for the emergency military road and airfield stabilization category. It was determined, however, that the effectiveness of quicklime is extremely dependent upon initial soil water content and that, particularly in the absence of sufficient water for hydration, the quicklime actually may be detrimental to the soil.

In the field, the lean clay soil at an initial water content such that it had a CBR of 4 was treated with both 4 and 8% quicklime concentrations (in an attempt to achieve stabilized-soil layers of varying characteristics), and compacted in 4-in. layers on a 4-CBR subgrade to a 16-in. thickness indicated by Corps of Engineers flexible pavement design curves as necessary to protect the subgrade. Traffic tests showed that the quicklime-stabilized soil layer was sufficiently strong and well compacted to withstand minimum traffic requirements for emergency military roads and airfields. Of possible advantage in terms of thickness requirements was an observed increase in subgrade bearing capacity, believed to have resulted from the removal of subgrade water by the hydration of overlying quicklime-treated soil. The tests showed, however, that the exposed quicklime-soil surface was not adequately resistant to abrasion by traffic, nor was abrasion lessened by application of a commercial road oil; thus a need is indicated for some type of supplementary protective wearing surface.

It is recommended that investigations of quicklime as a soil stabilizer be continued to determine more thoroughly its capabilities and limitations for military application, and to explore the possibility of improving its effectiveness by chemical modification or the use of secondary additives.

SOIL STABILIZATION

INVESTIGATIONS OF QUICKLIME AS A STABILIZING MATERIAL

PART I: INTRODUCTION

Purpose and Scope

1. This report summarizes the results of laboratory and field investigations to determine the soil stabilization capability of quicklime in a moderately wet, fine-grained soil. The investigation comprises a portion of the research directed toward developing means of creating or maintaining in soils the physical characteristics required to support the traffic of certain military operations.

Background

2. A major objective of the soil stabilization research program is to develop materials which, when added to fine-grained soils of moderate initial stability, will provide soil surfaces of sufficient strength to sustain loadings by vehicles or aircraft during military operations. The soil-stabilizing material must be one that can be placed with a moderate construction effort and that will be effective within 24 hr after construction. On the basis of anticipated operational requirements for roads such as frontline main supply routes or bridge approaches, and for Army airfields where rotary-wing and lightweight fixed-wing aircraft will operate, it is desired that the stabilized soil be able to sustain wheel loads of about 10,000 lb for a minimum of 2000 coverages.* These requirements are representative of situations referred to in previous soil stabilization investigation reports, and hereafter in this report, as "category 2" stabilization.

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* Representing revised traffic requirements based on WES Office Memorandum dated 15 April 1958, subject, "Soil Stabilization Requirements for Army Airfields." These requirements supersede previous tentative requirements proposed in WES memorandum dated 6 February 1956, subject, "Proposed Long-Range Plan of Test for Soil Stabilization."

3. Laboratory investigations conducted by the Massachusetts Institute of Technology under contract DA 22-079-eng-171 have shown that quicklime is an effective stabilizer for very wet clay soils having practically no initial stability. A subsequent laboratory and field study by the Waterways Experiment Station (WES)* showed that quicklime was capable of improving significantly the strength and trafficability characteristics of very wet and completely unstable soils. Based on the results of these studies, it was decided to investigate the possible applicability of quicklime for the stabilization of soils of moderate initial water content, and to determine its potential for meeting category 2 stabilization requirements.

Objectives

4. The primary objective of this investigation was to determine, by laboratory and controlled field tests, the ability of quicklime to meet emergency military road and airfield stabilization requirements. In addition, it was hoped to obtain information from the field tests that would result in a better understanding of the behavior of stabilized-soil surfaces under repetitive traffic loadings. Also, because lime-stabilized soil is known to abrade readily, it was desired to determine the severity of abrasion of the quicklime-treated surface under traffic and the possible need for a supplementary dustproofing treatment or protective wearing surface.

Test Program

5. The test program included laboratory investigations, and a field investigation consisting of the construction and traffic testing of a test section. The laboratory investigations were performed in two general phases: (a) preliminary tests to determine the ability of quicklime to

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* U. S. Army Engineer Waterways Experiment Station, CE, Soil Stabilization; Initial Laboratory and Field Tests of Quicklime as a Soil-Stabilizing Material, Technical Report No. 3-455, Report 2 (Vicksburg, Miss., August 1958).

satisfy specified minimum strength requirements, to examine the effect of selected percentage treatments of quicklime on soil characteristics, and to study variables that may influence the effectiveness of quicklime; and (b) supplementary tests conducted during construction of the field test section on field-mixed material to obtain an estimate of the strength developed by the stabilized-soil surface. The field test section, 13 ft wide by 100 ft long, was designed to have a 16-in.-thick surface layer on a heavy clay subgrade having a CBR of 4. The surface of the test section consisted of a lean clay (loess), the first 40-ft length of which was stabilized with 8% quicklime (by soil weight), the next 40-ft length with 4% quicklime, and the last 20 ft was compacted, untreated soil. The two different stabilizer concentrations, selected on the basis of the preliminary laboratory tests, were employed to achieve surfaces with varied strengths and physical characteristics.

6. In addition, a commercial dust palliative (road oil), a resin membrane, and an asphalt surfacing were applied to certain areas of the section in connection with the abrasion-resistance studies. Traffic tests with a 10,000-lb single-wheel-load vehicle were started approximately 24 hr after completion of construction of the section. Several months after the application of 2000 coverages without failure, additional traffic with heavier wheel loads was applied (in connection with other unrelated WES investigations). Data obtained during the field test program included routine construction-control data, observations of traffic performance, frequent CBR measurements in the stabilized surface layer and subgrade, measurements of surface abrasion, and results of unconfined compressive strength tests of field-mixed, laboratory-compacted specimens.

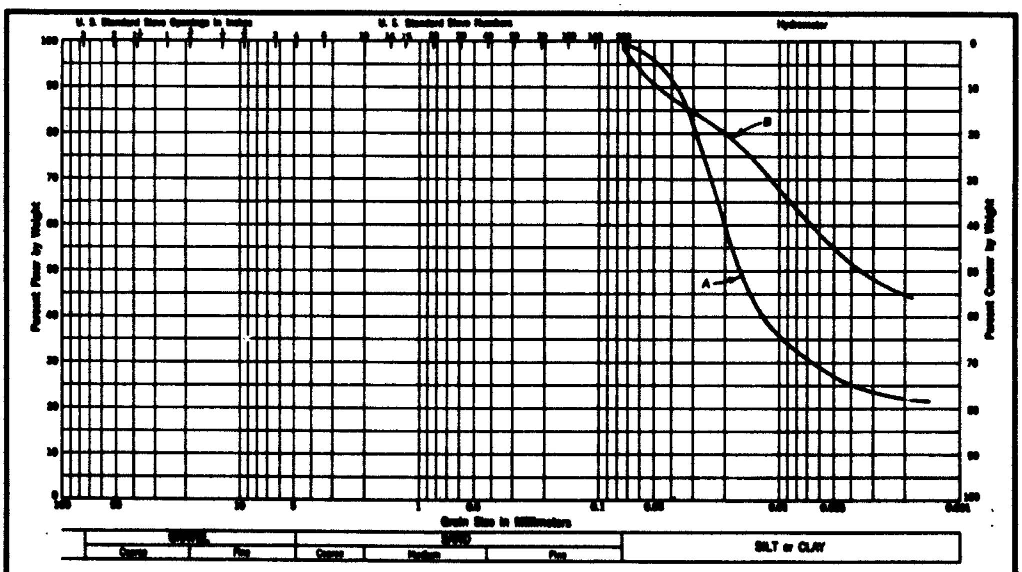
PART II: PRELIMINARY LABORATORY INVESTIGATION

7. Before a soil stabilizer is selected for field testing, laboratory investigations are conducted to determine the ability of the stabilizer to satisfy specified minimum strength requirements. Upon satisfactory compliance with these requirements, the stabilizer is subjected to further laboratory study to define more thoroughly its stabilizing capabilities.

Materials Used

Soil

8. A lean clay (loess) soil native to the WES grounds and adjacent areas was used in the laboratory tests. The soil was taken from stockpiled material subsequently employed in the construction of the stabilized surface of the field test section. The soil has Atterberg limits and gradation as shown in fig. 1 (soil A), and classifies as CL according to the



Number	Depth	Natural Moisture	L L	P. L	P. I.	Classification
A	STOCKPILE		43	23	20	LEAN CLAY (LOESS), CL
B	STOCKPILE		73	25	48	HEAVY CLAY (BUCKSHOT), CH

Fig. 1. Soil classification data

Unified Soil Classification System. The soil was low in organic content, contained some carbonate concretions, and had a pH value of 7.7 (slightly alkaline).

Stabilizers

9. A technical grade, powdered quicklime (calcium oxide) supplied by a commercial chemical company was employed in the preliminary laboratory test program. This material is an anhydrous powder which reacts readily with water to form hydrated lime, generating heat during the hydration process. In addition to the quicklime tests, limited comparison tests were conducted using a technical grade hydrated lime (calcium hydroxide) as the stabilizing material.

Initial Evaluation Tests

Test criteria and procedures

10. To provide a means for evaluating potential stabilizers in the laboratory, specific test criteria have been adopted based on estimates of strength required to accomplish a given stabilization objective. For category 2 stabilization, it is desired to increase the strength of a soil from an initial CBR of 4, representing the weakest condition considered feasible to stabilize for the intended purpose, to a CBR of 20. Assuming an adequate thickness of stabilized soil to protect the weaker subgrade, it has been estimated that a minimum CBR of 20 is required in the compacted, treated layer to prevent its failure by shear under the applied traffic load. Further, it is necessary that the required strength increase be achieved within 24 hr after construction, and without benefit of drying during the curing period. To simplify the initial laboratory screening and evaluation of potential stabilizers, an alternative strength criterion based on the unconfined compressive strength test has been adopted. From approximate correlations of CBR and unconfined compressive strength, it has been determined that a stabilizer capable of increasing the compressive strength of a soil from an initial 20 to 25 psi to a minimum of 100 psi after 24 hr without benefit of drying would warrant further examination and consideration for field testing as a category 2 stabilizer.

11. The following test procedures were employed during the initial

laboratory tests with the quicklime and hydrated lime. The test soil was processed and permitted to achieve moisture equilibration at about 23% water content. This water content results in an unconfined compressive strength of about 20 psi for the compacted, untreated soil. The stabilizer was added to the wet soil and blended in thoroughly by hand-mixing. The Harvard miniature compaction apparatus was used to mold specimens 1-5/16 in. in diameter by 2.82 in. long. The treated soil was placed in the molds in five layers, and each layer was compacted with 10 tamps of a 40-lb spring tamper; this compaction effort resulted in densities close to those which would be obtained using the standard Proctor or AASHO compaction effort. Following its extrusion from the mold, the specimen was cured for 24 hr under 100% relative humidity conditions, and then tested to failure in unconfined compression.

Test results

12. The results of the initial laboratory evaluation tests are shown in table 1. In all cases, the soil water content was 23% prior to the

Table 1

Results of Laboratory Evaluation Tests of Lean Clay Stabilized with Quicklime and Hydrated Lime

	As Molded		After 24-hr Humid Cure*		
Treatment	Water Content %	Dry Density lb/cu ft	Water Content %	Dry Density lb/cu ft	Unconfined Compressive Strength psi
Untreated soil (control)	23.0	101.0	22.8	101.4	21
Quicklime**					
3%	21.1	102.0	20.7	102.5	95
5%	20.4	100.2	19.8	102.0	137
8%	18.7	96.8	18.1	99.8	171
Hydrated lime**					
3%	21.8	101.8	21.5	101.9	67
5%	21.9	99.9	21.3	101.1	85
8%	21.0	98.3	20.5	99.8	95

Note: Specimens were compacted in five layers with 10 tamps of 40-lb spring tamper per layer.
Water contents are based on total weight of dry solids.
* Test results represent the average of two specimens.
** Percentages of stabilizers are based on dry soil weight.

treatments indicated (about 3% wet of standard Proctor optimum for the untreated soil). It is seen that treatment with quicklime resulted in a marked increase in the 24-hr humid-cure compressive strength compared with that of the untreated soil. Stabilization with hydrated lime also resulted in a strength improvement, but considerably less than that produced by quicklime for equal percentage treatments. The influence of both types of lime on the compaction water contents and compacted densities of the soil-lime admixtures are shown also in table 1. The decreased water contents are attributable to the increase in total solids content contributed by the limes, and in the case of quicklime, a further reduction is obtained as a result of the hydration process. With both materials, the strength continued to increase with greater concentrations of stabilizer to the maximum 8% treatment level. The effects of the lime treatments on the compressive strength are shown graphically in fig. 2. Based on the data from these initial tests, it was evident that quicklime, when applied to the lean clay in a quantity ranging from slightly greater than 3% by dry soil weight to the maximum 8% examined, was capable of improving the compressive strength sufficiently to meet the 100-psi minimum laboratory criterion established for category 2 stabilization.

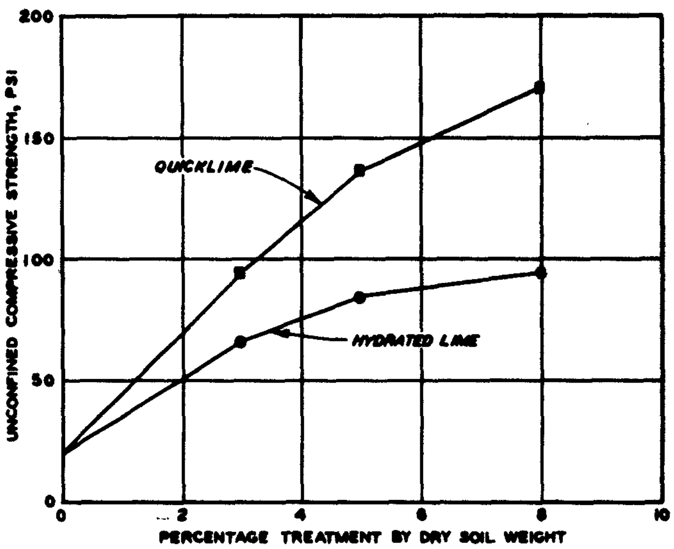


Fig. 2. Effect of lime on 24-hr humid-cure strength of lean clay at initial water content of 23%

Comprehensive Preliminary Tests

13. On the basis of the encouraging results obtained in the initial evaluation tests, it was decided to examine further and more comprehensively

the effect of quicklime on various physical properties of the test soil. These tests were conducted using soil stabilized with quicklime at treatment concentrations of 4 and 8% by dry soil weight. The 4% treatment was selected as representing a low-strength stabilization, but exceeding the minimum strength requirement, while the 8% treatment was chosen for its high-strength stabilization capability.

Effect of cure time on strength

14. Tests were conducted to determine the influence of curing time on the unconfined compressive strength of the test soil stabilized with 4 and 8% quicklime. The stabilizer was mixed with soil at an initial soil water content of 23%, and the admixture was compacted with the Harvard apparatus in five layers with 10 tamps of the 40-lb spring tamper per layer. The specimens were then cured at 100% relative humidity for varying lengths of time ranging from 2 hr to 28 days. At the end of a specified curing period, the specimens were tested to failure in unconfined compression. The results of these tests are given in table 2, and the strength-curing

Table 2

Effect of Curing Time on Strength of Lean Clay Stabilized with Quicklime

Percentage Quicklime Treatment*	Curing Time	As Molded Water Content %	As Molded Dry Density lb/cu ft	As Tested** Water Content %	As Tested** Dry Density lb/cu ft	As Tested** Unconfined Compressive Strength psi
4.0	0	20.6	103.2	20.9	104.0	70
	2 hr	20.7	102.9	20.5	104.3	98
	7 hr	19.9	99.3	19.8	101.5	102
	1 day	19.3	99.2	19.8	101.4	110
	3 days	20.4	100.2	19.7	102.4	154
	7 days	20.2	99.8	19.7	102.1	166
	14 days	20.8	100.6	19.8	102.8	215
	28 days	20.4	100.5	19.2	102.3	268
8.0	0	17.8	95.5	18.2	96.4	74
	2 hr	18.6	101.8	18.2	102.1	149
	7 hr	18.6	99.0	18.0	101.3	155
	1 day	18.7	96.8	18.1	99.8	170
	3 days	18.1	95.1	18.4	97.6	260
	7 days	17.6	93.8	17.4	96.4	286
	14 days	18.0	95.9	17.8	98.3	362
	28 days	18.0	95.3	17.3	98.0	425

Note: Specimens were cured under 100% relative humidity conditions.
Specimens were compacted in five layers with 10 tamps of 40-lb spring tamper per layer.
Water contents are based on total weight of dry solids.
* Based on dry soil weight.
** Test results represent the average of two specimens.

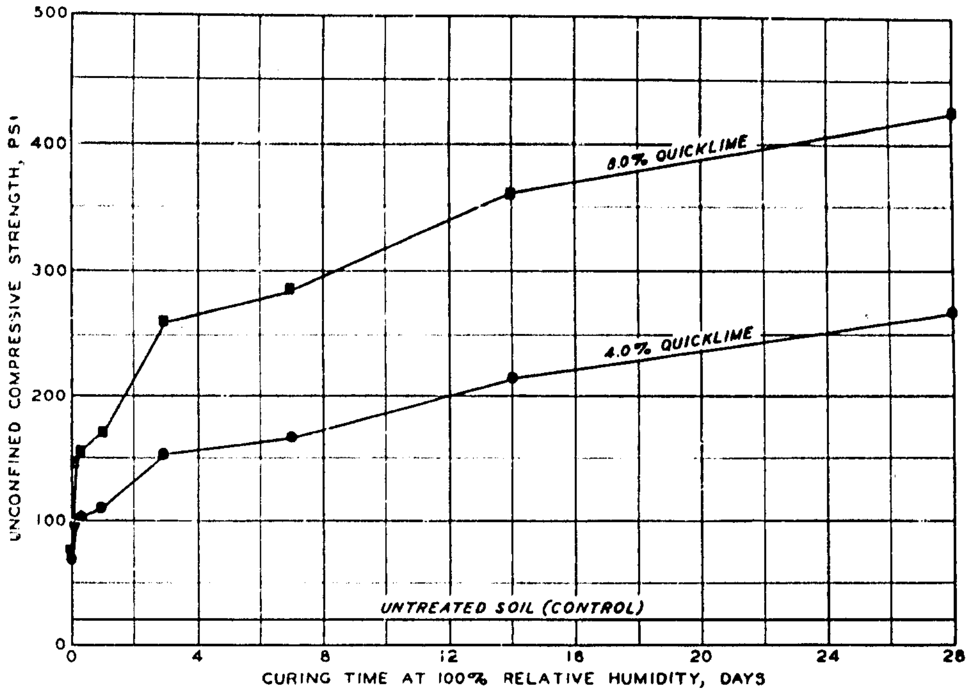


Fig. 3. Strength versus curing time for lean clay stabilized with quicklime

time relation is plotted in fig. 3. Specimens tested immediately after molding showed a significant increase in strength compared with the untreated soil strength, resulting probably from the reduction in water content due to the hydration of the quicklime. The strength increased rapidly during the early stages of curing and continued to increase with time, but at a diminishing rate. From fig. 3 it is apparent that the strength development was nearly complete after 28 days. Throughout the 28-day curing period, the 8% quicklime treatment resulted in greater strengths than the 4% treatment.

Atterberg limits

15. Atterberg limits tests were conducted to determine the effect of quicklime on the plasticity characteristics of the soil. Specimens with 4 and 8% quicklime were compacted and cured for 24 hr at 100% relative humidity, after which they were pulverized and screened over a No. 40 sieve. The Atterberg limits of this material, determined by standard methods, were as follows:

Treatment	Liquid Limit	Plastic Limit	Plasticity Index
Untreated soil (control)	43	23	20
4% quicklime	46	30	16
8% quicklime	47	30	17

Both the liquid limit and in particular the plastic limit of the soil were increased by the addition of quicklime, the net effect resulting in a slight reduction in the plasticity index. The increased limits are the result of a flocculating action of the lime which increases the capacity of the treated material to hold water. Further, it is apparent from the results that the addition of either 4 or 8% quicklime to the soil has very nearly the same effect on the plasticity characteristics.

CBR strengths

16. Both soaked and unsoaked laboratory CBR tests were made on the soil stabilized with 4 and 8% quicklime. The CBR specimens were compacted in 6.0-in.-diameter by 4.5-in.-high molds with an effort of 12 blows on each of five layers using a 10-lb weight and a drop of 18 in. (equivalent to standard Proctor effort). The initial water content of the soil prior to addition of the quicklime was 23%. The specimens for the unsoaked test were cured for one day at 100% relative humidity before testing. Specimens for the soaked test were immersed in water immediately after molding and allowed to remain therein under a 10-lb surcharge weight for four days before testing. Untreated soil specimens were prepared also and their soaked and unsoaked CBR's determined. The results of these tests are summarized in table 3. After one-day curing at essentially 100% relative humidity, CBR strengths of 53 and 89 were obtained for specimens prepared with 4 and 8% quicklime, respectively. This represents a substantial strength increase compared to the untreated soil. The soaked CBR data indicate that high strength is developed by the quicklime-soil admixture even while curing under water. Since the soaking period was begun immediately after compaction, the strengths had developed while considerable water was present in the voids of the treated specimens. This implies that the stabilizing process continues in the presence of excess water, although the ultimate strengths developed are probably less than those which would result if the excess water was absent. The CBR values resulting from the 8% treatment

Table 3

Laboratory CBR Test Results on Lean Clay

Stabilized with Quicklime

Percentage Quicklime Treatment*	Cure Time and Method	As Molded Water Content %	As Molded Dry Density lb/cu ft	As Tested Water Content %	As Tested Dry Density lb/cu ft	CBR
Untreated soil (control)	1 day humid	23.4	101.0	23.0	101.0	3.0
	4 days soak	23.6	100.7	23.4	100.4	2.1
4.0	1 day humid	21.0	104.0	20.5	104.3	53
	4 days soak	21.2	102.8	21.5	102.8	63
8.0	1 day humid	19.5	99.7	18.4	100.6	89
	4 days soak	19.3	100.6	22.1	100.1	86

Note: Specimens were compacted with effort equivalent to standard Proctor effort.
Water contents are based on total weight of dry solids.
Unsoaked specimens were sealed in compaction molds.
Soaking of specimens started immediately after molding.
* Based on dry soil weight.

were higher than those from the 4% treatment, substantiating the greater unconfined compressive strengths previously observed at this higher treatment level. At both concentrations, the CBR values obtained greatly exceeded the estimated minimum CBR of 20 necessary to satisfy the requirements for category 2 stabilization.

Compaction and strength characteristics

17. To determine the effect of quicklime on the compaction and strength characteristics of the soil, a series of tests was conducted using the Harvard compaction apparatus to prepare specimens. Specimens of untreated and quicklime-treated soil were molded at various initial soil water contents and with three different compaction efforts. The treated specimens were cured for 24 hr at 100% relative humidity and then tested in unconfined compression. The untreated soil specimens were tested immediately after molding. The results of this compaction and strength

study are shown in fig. 4. Examination of the density-water content relations in fig. 4 shows that the maximum compacted density of the soil is decreased as the percentage of quicklime is increased, whereas the optimum water content for compaction (on the basis of total weight of solids) was increased by the addition of quicklime. These effects on the compaction characteristics are attributable primarily to the aggregating or flocculating action of the quicklime on the soil. Also of interest is the effect of compaction effort on the strengths and densities of the treated soil. With both treatment concentrations, as the compaction effort was increased, the optimum water content was reduced and greater maximum compacted densities were obtained. The maximum or peak strength obtainable with 8% quicklime increased significantly with increasing compaction effort; however, in the case of 4% quicklime, the peak strength increased modestly, then decreased, as the compaction effort was increased. With the exception of the 4% treated material compacted at the high effort (50 tamps per layer, 40-lb spring), the peak strengths were generally obtained at water contents approximately 1 to 2% dry of optimum. For specimens compacted with the low effort (10 tamps per layer, 20-lb spring), only slightly greater strengths were obtained with 8% quicklime as compared with the 4% treatment, although both concentrations resulted in a significant increase in the strength of the soil.

18. It is apparent also from the data that the strength is highly dependent upon the water content at which molding of the specimen is accomplished. In general, maximum strengths were achieved at water contents ranging from 18 to 22% based on the total weight of dry solids. Taking into consideration the hydration of the quicklime and its contribution to the total solids content of the admixture, maximum strengths were obtained with 4% quicklime at an actual initial soil water content ranging from 21 to 25%. Similarly, maximum effectiveness with 8% quicklime was achieved at an initial soil water content ranging from 23 to 27%. Increasing the initial soil water content above the ranges indicated caused increasingly greater reductions in strength. This is perhaps a result of the combined influence of lower compacted densities at the higher water contents and a reduction in the cementing effectiveness of the lime in the presence of excess water. At soil water contents lower than the ranges shown,

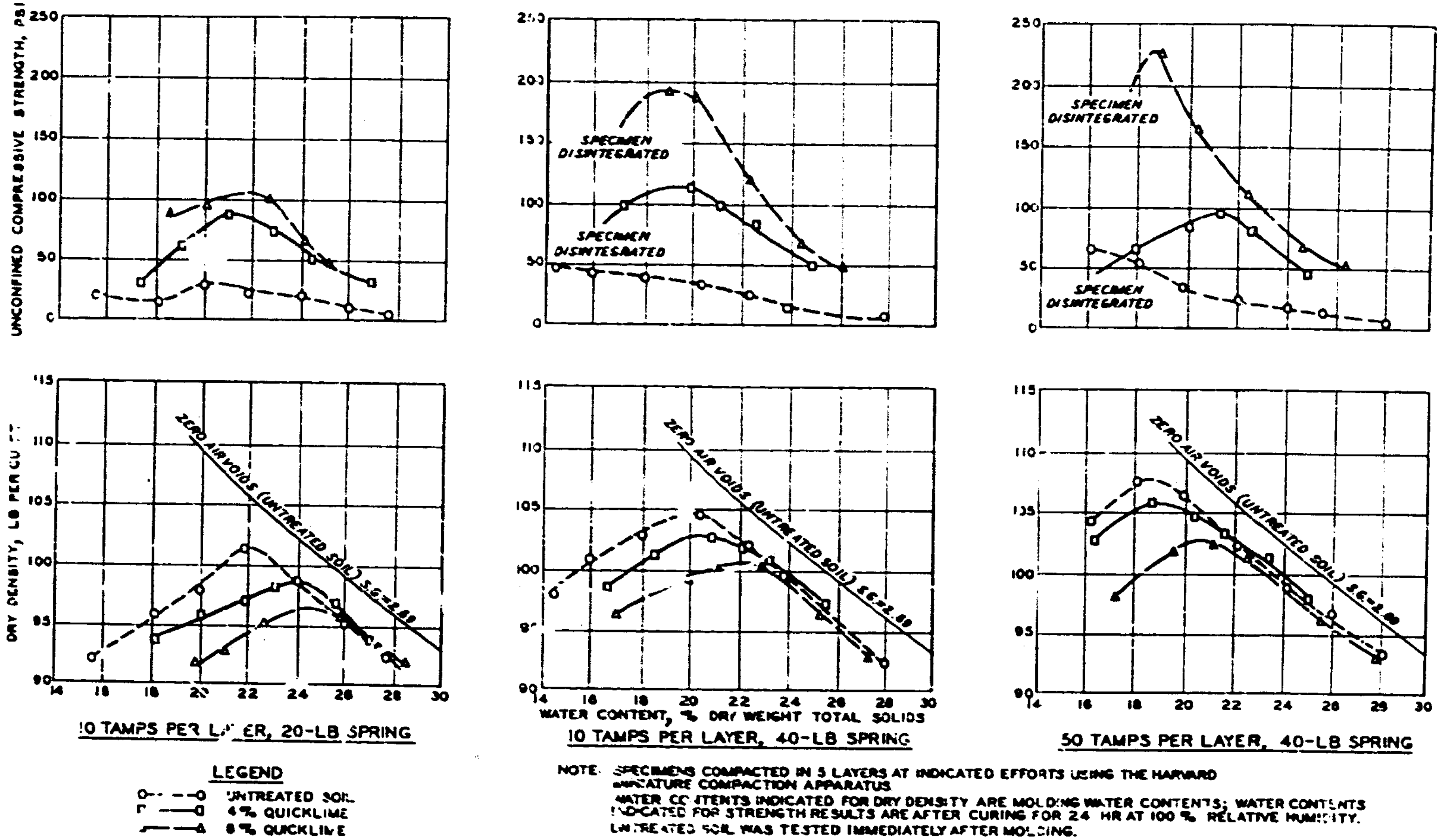


Fig. 4. Compaction and strength characteristics for lean clay stabilized with quicklime

decreased strengths also were observed. Further, as the initial water content of the soil was reduced to some critical value (approximately 19 and 21% for the 4 and 8% quicklime treatments, respectively), a gradual disintegration of the specimens was observed during the curing period accompanied by a considerable expansion of the treated mass. This phenomenon is believed to have resulted from internal stresses developed by a combination of (a) volume expansion of the quicklime, and (b) excessive heat evolution during the hydration process in the absence of sufficient available free water. It is evident from these compaction data that the maximum effectiveness of quicklime stabilization of the lean clay test soil is obtained at an initial soil water content corresponding to the maximum anticipated for the category 2 stabilization situation. The data indicate also the desirability of careful control of both water content and compaction to realize the full benefit of stabilization with quicklime.

Effect of delay between mixing and compacting

19. Because quicklime is a rapidly reacting material, tests were run to determine the effect on strength development of a time lapse between the mixing operation and the compaction of the soil-lime admixture. Specimens treated with quicklime were molded with the Harvard apparatus (five layers, 10 tamps per layer, 40-lb spring tamper) both immediately after mixing and 1/2 hr after the mixing operation. During the 1/2-hr delay period, the admixture was left uncovered. After compaction, the specimens were cured for 24 hr at 100% relative humidity and tested in unconfined compression. The following results were obtained:

Quicklime % of Dry Soil Weight	Time After Mixing Operation hr	As Molded		After 24-hr Humid Cure		
		Water Content %	Dry Density lb/cu ft	Water Content %	Dry Density lb/cu ft	Compressive Strength psi
4.0	0	21.7	100.7	21.3	102.3	116
	1/2	20.6	94.4	20.7	96.2	72
8.0	0	19.0	96.2	18.8	98.1	164
	1/2	18.3	92.2	18.6	93.5	88

Note: Water contents are based on total weight of dry solids.

It is apparent that a significant reduction in strength is caused by delaying compaction for as little as 1/2 hr. It should be noted also that the compacted density is considerably less after the time lapse. It is believed that the processes of flocculation and cementation begin immediately upon incorporation of the quicklime in the soil, and any subsequent disturbance of the material, such as compaction, tends to destroy the bonds that have developed to that time. Thus, to obtain maximum effectiveness of quicklime stabilization, it appears necessary to accomplish compaction as soon as possible after the mixing of the lime with the soil.

PART III: FIELD INVESTIGATION

20. Based on the results of the preliminary laboratory studies, the field investigation was undertaken to determine the stabilizing effectiveness of quicklime in the field and the behavior of a quicklime-stabilized soil surface when subjected to actual traffic loads. To obtain a better understanding of the effect of strength on the performance of the stabilized-soil layer under traffic, the test program included the construction and testing of soil surfaces treated with both 4 and 8% quicklime concentrations. Because it was suspected that an exposed lime-stabilized soil would be subject to abrasion by traffic, tests were conducted to investigate this aspect and to examine possible methods for reducing or eliminating the abrasion problem if, in fact, it was found to exist. In addition, an untreated soil section for control and comparison tests was compacted at a water content representing the initial condition of the soil prior to the quicklime stabilization.

Location and Layout of Test Section

21. The test section was constructed under shelter so that it would be affected as little as possible by weather conditions. It was 13 ft wide by 100 ft long. The first 40-ft length of the section was stabilized with 8% quicklime; the next 40 ft with 4% quicklime; and the final 20 ft was untreated compacted soil. These differently treated areas will be referred to throughout the remainder of this report as sections 1, 2, and 3, respectively. Shoulders and turnaround areas of compacted soil were provided at the sides and ends of the section to permit construction and trafficking equipment to make necessary maneuvers. Fig. 5 shows the layout profile and a typical cross section of the test section.

Subgrade Preparation

Material

22. A heavy clay soil (locally known as "buckshot" clay) was used to construct the subgrade. The soil had Atterberg limits and particle size

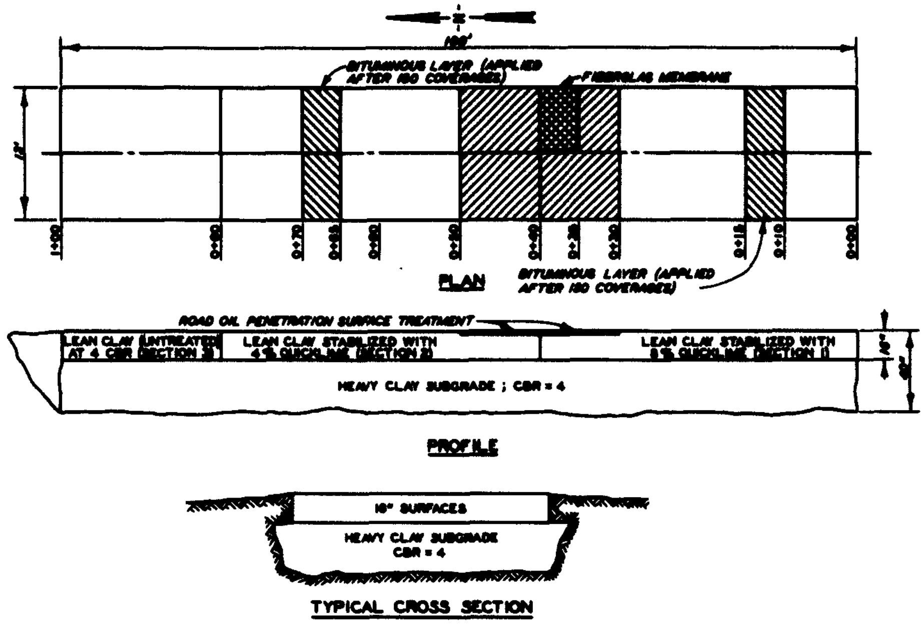


Fig. 5. Test section layout

distribution as shown for soil B in fig. 1, and classified as CH according to the Unified Soil Classification System. Laboratory compaction data and CBR relations for this material are given in fig. 6. This soil was selected for the subgrade because of its ability to provide a uniform and

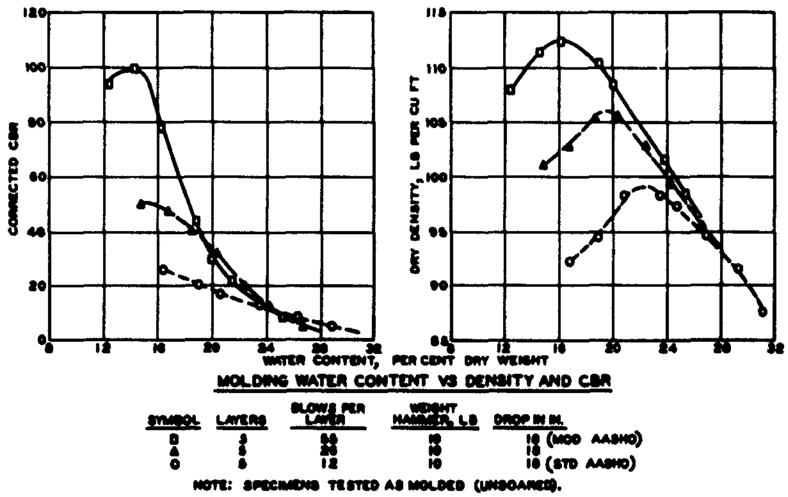


Fig. 6. Compaction and CBR relations for heavy clay (buckshot) used to construct test section subgrade

generally stable low CBR with a minimum of construction effort and control.

Construction

23. The existing soil in the test section area was excavated to a depth of 40 in. below anticipated final surface grade and wasted. The subgrade soil, previously processed and stockpiled at a water content required to achieve a compacted CBR of 4, was placed in the excavation and compacted in five lifts to result in a total subgrade thickness of 24 in. Each lift was compacted by applying eight coverages with a self-propelled, empty, rubber-tired roller of 23,500-lb gross weight distributed uniformly on seven wheels with tires inflated to 100-psi pressure. Control tests during construction of the subgrade showed that an average CBR of 3.7 and an average dry density of 89.7 lb per cu ft were achieved at an average water content of 30.4%.

Stabilized-Surface Preparation

Materials used

24. Soil. The lean clay (loess) soil described in paragraph 8 and used in preliminary laboratory investigations was used in the construction of the stabilized-soil layer and the untreated, compacted soil layer.

25. Stabilizer. A commercially produced, pulverized, high-calcium quicklime was used in the field tests. Although a chemical analysis was not made of the specific material, the following average composition of high-calcium quicklimes is typical:*

Component	%	Component	%
Calcium oxide (CaO)	93.25 to 98.00	Aluminum oxide (Al_2O_3)	0.10 to 0.50
Magnesium oxide (MgO)	0.30 to 2.50	Water (H_2O)	0.10 to 0.90
Silica (SiO_2)	0.20 to 1.50	Carbon dioxide (CO_2)	0.40 to 1.50
Ferric oxide (Fe_2O_3)	0.10 to 0.40		

Since quicklime generates considerable heat during hydration, it is somewhat hazardous to work with. To minimize possibility of skin burns, suitable protective clothing was furnished to individuals handling the material.

* Reported in National Lime Association, Chemical Lime Facts, Bulletin 214 (Washington, D. C., 1951).

26. Dust preventive. A commercial road oil, found to be effective as a dust preventive in a previous WES study,* was applied to a portion of the stabilized surface as a supplementary penetration treatment. The road oil is a rapid-curing liquid blend of a volatile distillate and a non-asphaltic viscous petroleum base.

Design

27. To satisfy the category 2 requirements, a stabilizing material must provide a stabilized-soil layer of sufficient strength and thickness over a subgrade with a CBR of 4 to withstand traffic of wheel loads of as much as 10,000 lb for at least 2000 coverages. As presently conceived, a thickness of stabilized soil equivalent to that specified by Corps of Engineers flexible pavement design curves is required to prevent failure of the underlying subgrade by the traffic load for at least the number of coverages involved. For a 10,000-lb wheel load and 70-psi tire pressure, representing the design traffic load for this investigation, flexible pavement design curves indicate that a surface layer 16 in. thick is necessary to protect a 4-CBR subgrade for at least 2000 coverages of traffic.** With adequate thickness provided to protect the subgrade, the stabilized-soil layer must be sufficiently strong to withstand within itself the stresses of the imposed traffic. From existing knowledge of traffic on unsurfaced soils, from flexible pavement data, and from information available to date on the behavior of stabilized-soil surfaces under traffic, it has been estimated that a minimum CBR of about 20 is required for a moderately flexible, stabilized-soil layer to support anticipated category 2 traffic. Equally as important as sufficient strength development, however, is the necessity for adequate compaction of the stabilized-soil layer. Previous experience with stabilized soil has shown that insufficient densification during construction can result in a stabilized layer that may fail rapidly, not because of surface shear deformation, but because of excessive

* U. S. Army Engineer Waterways Experiment Station, CE, Dustproofing and Waterproofing of Soils; Field and Laboratory Investigations of Selected Materials, Technical Report No. 3-530, Report 1 (Vicksburg, Miss., December 1959).

** This design is based on WES flexible pavement curves for full operational airfields dated 21 October 1954. More recent revisions of pavement design have resulted in an adjusted requirement of 15 in. for the same load and coverage level.

differential consolidation caused by the applied traffic with attendant detrimental cracking and severe rut development. In an attempt to achieve an adequately mixed and compacted stabilized-soil layer of 16-in. thickness, construction in four 4-in. lifts was specified in the design, with successive lifts subjected to increased compaction effort. Although it is recognized that treatment and placement of the stabilized-soil layer in multiple lifts probably does not represent the most desirable or acceptable technique for actual military operations, the intent of this test was to determine the capability of the stabilizer when utilized in the most efficient manner possible. Thus, since a single, mixed-in-place layer of the required thickness cannot be properly constructed with existing equipment, construction in multiple lifts was specified.

Construction

28. The lean clay test soil was processed and stockpiled at an initial water content (about 23%) which would result in a CBR of 4 if the soil were compacted in the untreated state. The soil for each lift was transported by truck to the construction site where it was spread to a uniform thickness (about 5 in.) over the test section area and given one mixing coverage by a standard self-propelled Seaman Pulvi-mixer. The quicklime was spread by hand on the surface of the loose soil (fig. 7) in quantities sufficient to achieve an 8% treatment by dry soil weight for the

Fig. 7. Placing of quicklime on soil prior to mixing operation. Note protective masks and gloves worn by handlers

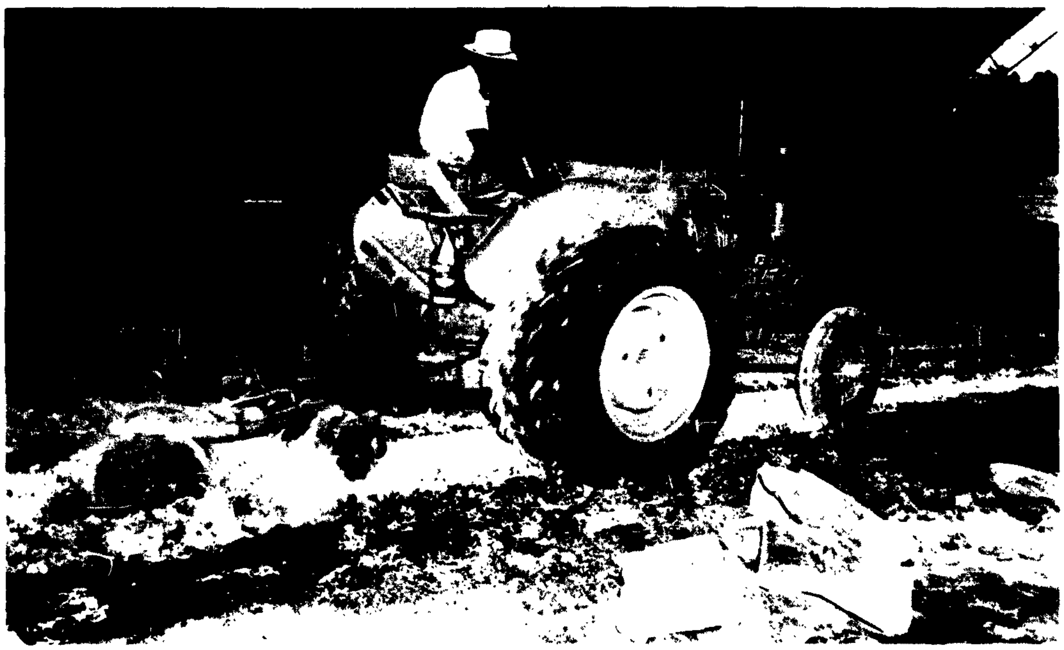


Fig. 8. Preliminary mixing of quicklime and soil with disk harrow

first 40-ft length (section 1) and 4% treatment for the next 40 ft (section 2). Immediately after placement of the quicklime, preliminary mixing was accomplished by one coverage of a 5-ft-wide disk harrow (fig. 8). Three coverages of a self-propelled Seaman Pulvi-mixer (fig. 9) completed

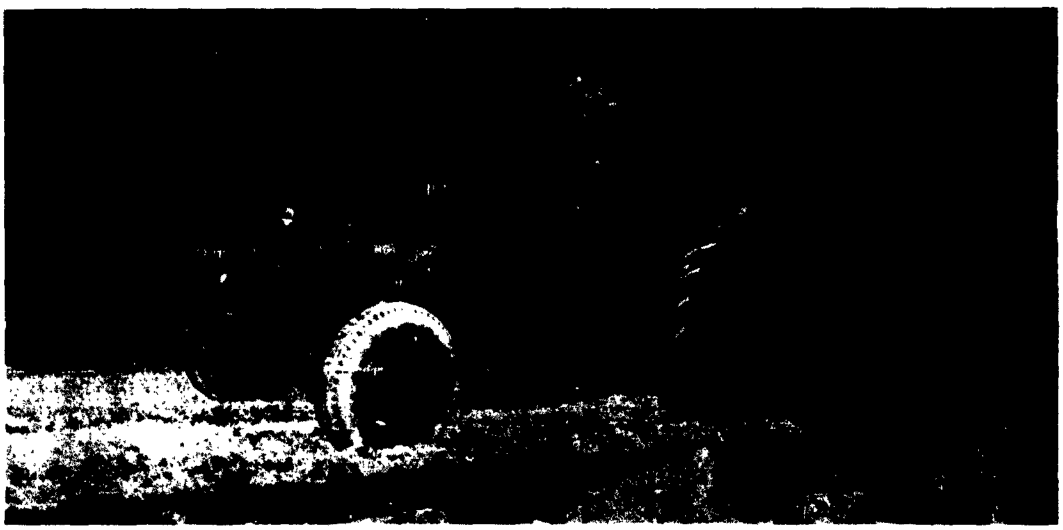


Fig. 9. Mixing of quicklime and soil with Pulvi-mixer

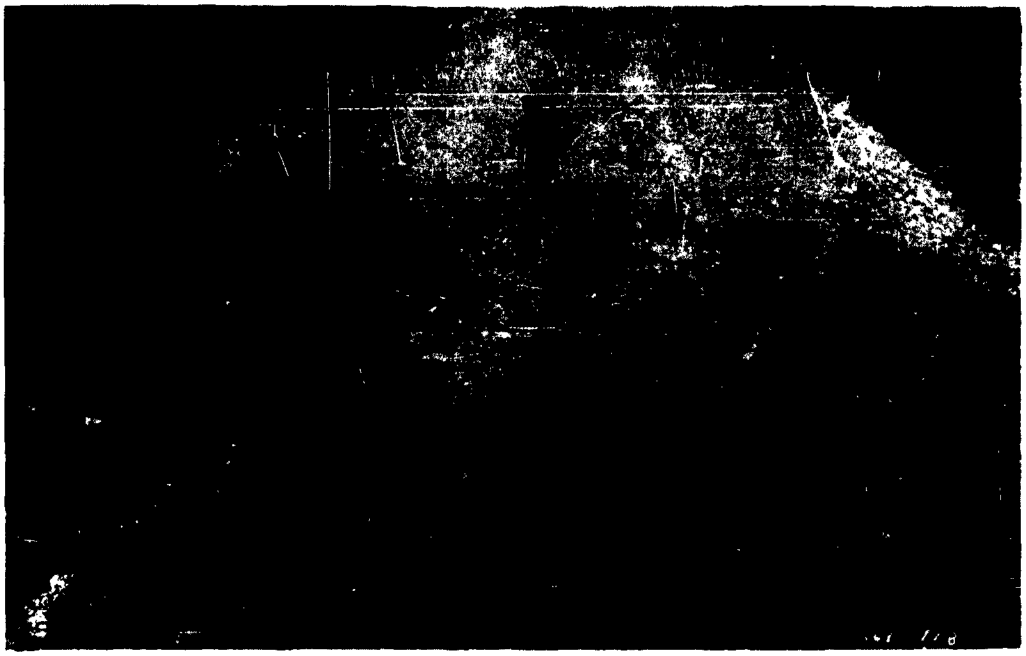


Fig. 10. Appearance of test section after mixing operation

the mixing operation within about 10 min. The appearance of the test section after the mixing operation and immediately before compaction is shown in fig. 10. Close-ups of the mixed soils are shown in fig. 11. The

Fig. 11. Comparisons of mixed material showing, from left to right, 4% admixture, 8% admixture, and untreated soil

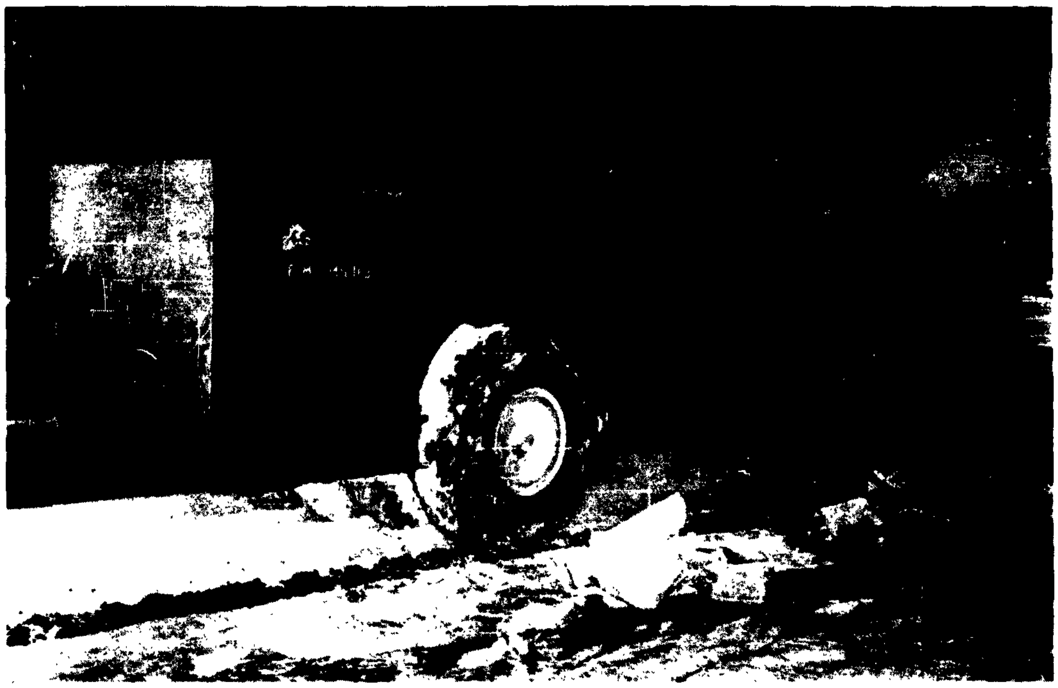


Fig. 12. Compaction of quicklime-treated test section

section was then compacted with six coverages of a towed, four-wheel, rubber-tired roller (fig. 12) loaded to a total weight of 22,500 lb for the first or bottom lift, 30,000 lb for the second lift, and 50,000 lb for the third and fourth lifts with tires inflated to 100-psi pressure. The total construction time from the beginning of the mixing operation to the completion of compaction was about 30 min for each lift. Following compaction of the final lift, the surface was fine-bladed, wetted lightly with water (except for the area receiving the penetration road oil treatment), and covered with a tarpaulin for the curing period. Data taken during the construction of the stabilized-soil layer included water contents before and after treatment with quicklime, and surface CBR, density, and water content immediately after the compaction of each lift. These data are summarized in table 4. The total constructed thickness of the stabilized-soil layer, as determined from later measurements in CBR pits, ranged from 15.9 to 17.1 in. with an average of 16.5 in. for both quicklime-treated sections.

Table 4

Construction Data for Quicklime-Stabilized Lean Clay Surface

Section	Avg Water Content, % Before Compaction: Untreated Soil	Treated Soil After Mixing	Test Results After Compaction of Each Lift: Station	Lift No.	Water Content %	Dry Density lb/cu ft	CBR*
1	22.7	18.7	0+20	1	17.3	86.3	9
(8% treated)	23.2	18.6		2	17.7	91.4	24
	22.6	18.8		3	17.4	94.9	27
	23.7	19.7		4	19.4	96.5	34
2	24.0	20.4	0+60	1	18.9	96.9	16
(4% treated)	23.2	20.8		2	19.5	99.0	27
	22.8	20.8		3	19.6	96.4	31
	23.7	21.5		4	21.2	101.9	26
3	22.7	--	0+90	1	22.9	100.4	4
(Untreated)	22.7	--		2	22.3	101.0	4
	22.9	--		3	23.2	100.5	4
	23.3	--		4	21.6	100.9	3

Note: Water contents are based on total weight of dry solids.
Each lift was compacted with six coverages of four-wheel, rubber-tired roller at 100-psi tire pressure with following gross weight:
(a) Lift 1 (bottom), 22,500 lb
(b) Lift 2, 30,000 lb
(c) Lifts 3 and 4 (top), 50,000 lb
* CBR values are averages of five values taken on surface only of each lift following compaction.

Application of dust preventive

29. Immediately after the construction of the final lift of stabilized soil, a spray penetration treatment of the road oil described in paragraph 26 was applied to a 20-ft length which included parts of both sections 1 and 2 as shown in fig. 5 (page 17). The oil was applied in a quantity of 0.25 gal per sq yd over the area indicated.

Supplementary surfacing materials

30. Although not originally a part of the planned test program, an opportunity arose in connection with another WES investigation to determine the possible advantages of a plastic membrane as a supplementary surfacing material. A polyester-resin-impregnated Fiberglas was sprayed from a special applicator onto the surface of the test section, covering a small area of section 1 with a thin, flexible membrane as indicated in fig. 5. A close-up of the plastic-Fiberglas membrane is shown in fig. 13. Fig. 14 is

Fig. 13. Close-up of resin-impregnated Fiberglas membrane surfacing

Fig. 14. Overall view of test section (facing north) prior to traffic testing

an overall view (looking north) of the completed test section just prior to beginning traffic tests, showing the areas treated with the road oil and the plastic membrane.

31. A bituminous surface treatment, placed after 150 coverages of traffic had been applied to the test section, was also investigated as a supplementary surfacing material. This consisted of a single-layer application of 0.25 gal per sq yd of 85-100 penetration asphalt on which limestone screenings passing the No. 4 standard sieve were rolled. This treatment was applied to portions of sections 1 and 2 as indicated in fig. 5.

Traffic Tests

Failure criteria

32. To provide a basis for evaluating the results of a traffic test, failure criteria must be established that will reflect with reasonable accuracy the behavior of a stabilized-soil surface subjected to traffic. Although flexible pavement design curves can be used to determine the required thickness of a stabilized-soil surface layer for a specific subgrade and traffic situation, the tolerable limits to which this layer can be stressed may differ greatly from those for a comparable thickness of flexible pavement construction. Failure of flexible pavements, upon which the CBR design curves were based, is considered to be the point at which either (a) detrimental shear deformation occurs in the base, subbase, or subgrade, resulting in ruts 1-1/2 to 2 in. deep, or (b) surface grooving of 1-1/2 to 2 in. occurs as a result of consolidation. The more likely failure is a combination of (a) and (b), resulting generally in detrimental surface conditions. In the case of a stabilized-soil surface, however, failure is considered to have occurred when the stabilized soil has reached a condition that significantly reduces its usefulness as a surface layer. This condition is determined by visual observations of the points at which (a) the surface appears to have lost its integrity and/or has become sufficiently damaged to permit ingress of water, or (b) ruts of 1-1/2 to 2 in. occur, which are considered to be deep enough to impede and/or imperil continued operations. Failure, as defined by these criteria, may result from surface shear displacement in the instance of a very weak surface, or as a

consequence of excessive differential consolidation under traffic, generally resulting from inadequate compaction during construction. Unless water is permitted to enter the underlying soil, failure of the subgrade should not occur since sufficient thickness of stabilized-soil construction is provided to enable the subgrade to withstand a specific number of coverages of the design load. The extent to which a stabilized-soil layer may be consolidated or deformed without detrimental cracking depends primarily upon its elastic and strength characteristics. For example, in the case of a brittle stabilized-soil layer, only a very small deformation may be tolerated before excessive cracking occurs, whereas a highly flexible stabilized surface may permit consolidation of as much as 2 in. without disruption of the surface layer.

Vehicle characteristics and traffic patterns

33. Initial traffic tests were conducted with a special 10,000-lb single-wheel-load test cart (see fig. 15). It was equipped with aircraft-type tires, size 34.00-9.9, 14 ply, which were inflated to 70-psi pressure, resulting in an average contact pressure of 87 psi. After 318 coverages were applied to the test section, one tire blew out, and examination of the tires indicated that rim-cutting was taking place due to underinflation.

Fig. 15. 10,000-lb single-wheel-load test cart

Therefore, a new set of tires was installed on the test cart, and the remaining traffic was run with tires inflated to 100 psi, resulting in a contact pressure of 95 psi. The rear wheels, which applied the load, were spaced 6 ft apart. Traffic was applied so that full coverage was obtained by the wheels over two 3-ft-wide paths, the center lines of which were 3 ft on both sides of the test section center line. Four passes of the vehicle were necessary to achieve one full coverage.

34. Although not originally scheduled in the test program, additional traffic was subsequently applied to the test section in connection with another WES traffic investigation conducted in an area adjacent to the quicklime-stabilized test section. A 25,000-lb single-wheel-load test cart having a 56.00-16, 24-ply tire inflated to 100-psi pressure (108-psi contact pressure) was run on sections 1 and 2 over an area not previously trafficked (i.e. along the center line of the test section). In addition, a 50,000-lb single-wheel-load test cart having a 25.00-28, 30-ply tire inflated to 100-psi pressure (104-psi contact pressure) tracked sections 1 and 2 in the left traffic lane previously trafficked by the 10,000-lb cart.

35. Additional traffic also was applied with the 50,000-lb load down the center-line path previously trafficked by the 25,000-lb load described above. This traffic was applied only in section 1 after it had been bladed off to about a 7-in. thickness in connection with another WES study.

Test results with
10,000-lb single-wheel load

36. General observations. Traffic with the 10,000-lb single-wheel-load test cart was begun on the test section approximately one day after construction was completed. The vehicle was immobilized on the first pass in section 3, which consisted of the untreated soil compacted to a CBR of 4. Average rut depth in section 3 after one pass was about 2 in. The test cart was winched out and subsequently, by building up considerable speed, was able to complete one coverage in section 3. Photograph 1 shows the failed condition of section 3 after one coverage. Traffic was continued on sections 1 and 2 during the next three weeks until a total of 2000 coverages had been applied. With the exception of raveling and abrading, the quicklime-stabilized soil surfaces were not affected detrimentally by the traffic. About one week after traffic was begun, shallow shrinkage cracks

were detected on the stabilized surfaces. The cracks were more prominent in section 2, but in neither section were they severe enough to influence the traffic tests except, perhaps, by contributing to increased abrading of the stabilized soil. The appearance of sections 1 and 2 prior to traffic and after 40, 250, 1000, and 2000 coverages is shown in photographs 2-11. A single-layer bituminous surface treatment was applied after the completion of 150 coverages and appears in the photographs taken thereafter.

37. By the time the tests were completed on sections 1 and 2, the untreated soil area (section 3, which had failed previously after one coverage) had dried considerably and formed a hard, cracked, surface crust to a depth of 5 or 6 in. It was decided to traffic this area further with the 10,000-lb load cart to observe the effect of this hardened surface crust on the behavior of the section under traffic. A total of 40 coverages was applied down the center line of the section before the vehicle became immobilized. Ruts were 6 to 8 in. deep at this time (see photograph 12).

38. Surface deflections and deformations. During the traffic tests measurements were made of surface deflections under the load and permanent deformation or rutting. Deflections of the surface directly under the tire remained constant throughout the test, ranging from 0.07 to 0.09 in., and were the same for both sections 1 and 2. Measured surface rutting or permanent deformation was relatively small, the majority occurring in the early stages of traffic. Average cross-section data for sections 1 and 2, taken at intervals of traffic, are plotted in fig. 16, which shows the surface deformation development across the width of the

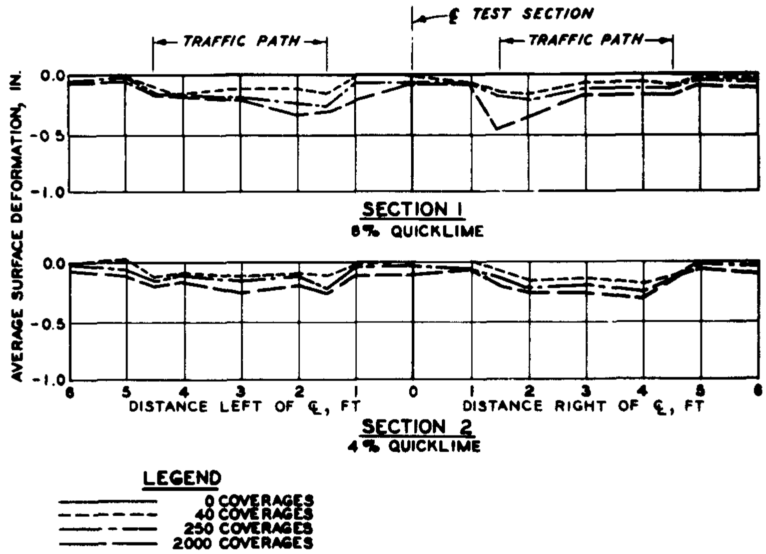


Fig. 16. Average cross-section data showing deformation of surface resulting from traffic with 10,000-lb single-wheel load

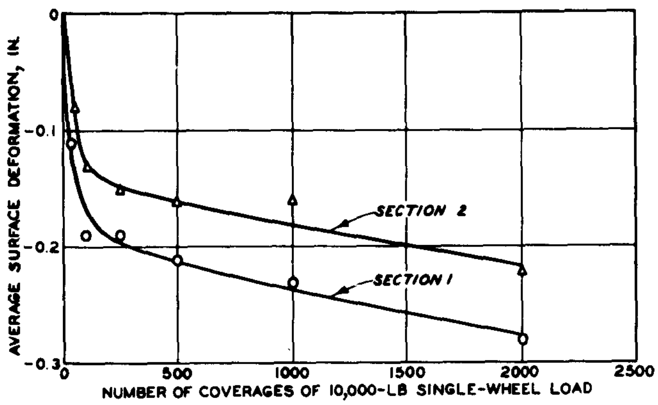


Fig. 17. Surface deformation versus number of coverages (from average traffic path center-line profile data), 10,000-lb single-wheel load

traffic paths. The progress of surface deformation with coverages for both sections is shown in fig. 17. It is seen that most of the consolidation by traffic had occurred by 100 coverages, and that consolidation continued thereafter at a fairly constant but reduced rate. It is suspected also that a small amount of the measured deformation represents a reduction in thickness of the stabilized layer as a result of surface abrasion. In any event, the observed surface deflections and deformations had no adverse effect on the integrity or ultimate traffic performance of the stabilized-soil layer.

39. Surface abrasion and dust formation. Quantitative measurements to determine the extent of abrasion of the stabilized-soil surface and formation of dust were made at intervals during the traffic test. To determine the amount of abrasion, a canvas template with a 4- by 2-1/2-ft rectangular section cut out of it (fig. 18) was positioned directly in the traffic path after a series of traffic coverages, and the abraded material within the 10-ft area was collected with a common, tank-type vacuum sweeper. The material collected was weighed and its particle size distribution determined. Measurements of abraded material were made after 40, 100, 250, 500, 1000, and 2000 coverages. Following this operation after each traffic interval, the entire test section was swept free of all remaining abraded material before traffic was continued. The results of the abraded material collections on sections 1 and 2, both with and without the road oil application, are plotted in fig. 19. The upper half of fig. 19 shows the accumulative weight of abraded material collected per square foot within the traffic path, and the lower half shows the amount of the total abraded material that was finer than the No. 200 sieve. It is of interest that section 2 (4% quicklime) abraded much less than section 1 (8% quicklime),

Fig. 18. Canvas template in position for collection of abraded material

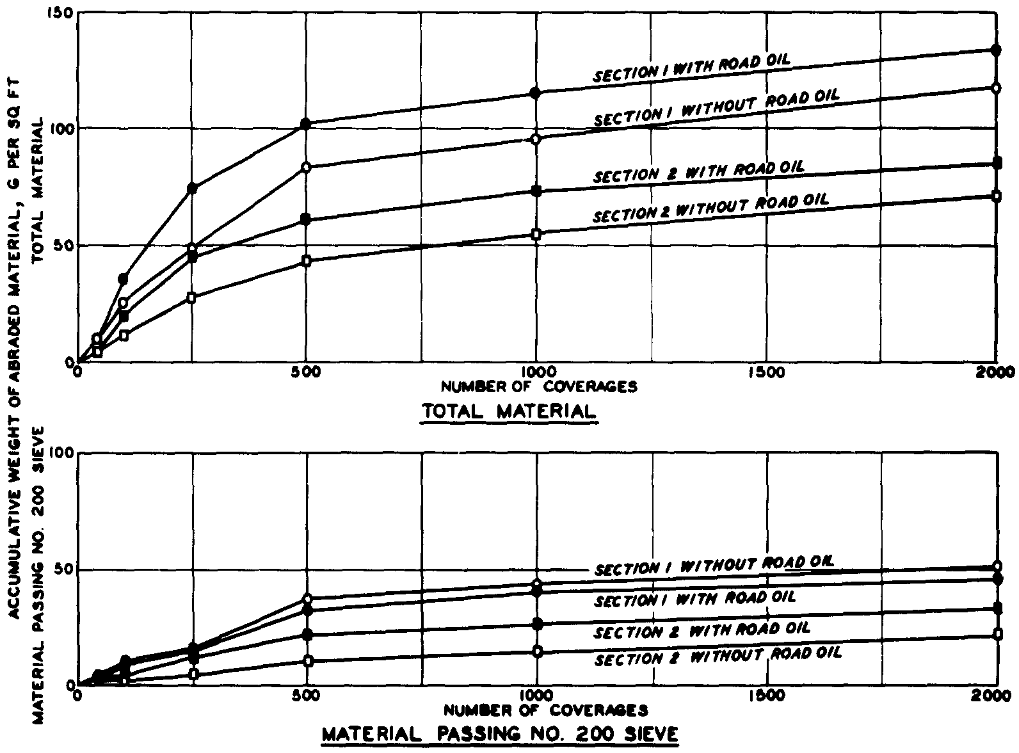


Fig. 19. Abrasion of stabilized surface by traffic of 10,000-lb single-wheel load

and that in neither section was the road oil treatment effective in reducing abrasion. The appearance of the various surfaces after 100 and 2000 coverages, comparing areas before and after collection of abraded materials, is shown in photographs 13-20. During the initial phases of traffic, loose agglomerations or "islands" of material were broken away from the stabilized-soil surfaces and, as may be seen in photographs 13-16, contributed to the abraded material. Continued traffic, however, compacted crushed material into the openings between these agglomerations and formed an essentially tighter-knit surface, as shown in photographs 17-20, after 2000 coverages.

40. Although not concerned directly with surface abrasion, observations were made of the condition of the supplementary plastic and bituminous protective surfacings during traffic. The sprayed plastic membrane showed no indication of damage from traffic, but did separate from the stabilized-soil surface at about 800 coverages. The appearance of the plastic surfacing after 2000 coverages is shown in photograph 21. Upon removal of the membrane, the underlying stabilized-soil layer was found to be in excellent condition (photograph 22) with no evidence whatsoever of cracking or surface deterioration. The bituminous treatment also proved to be a highly effective wearing surface on the stabilized soil (photograph 23), showing no distress during the traffic test.

41. CBR test results. Field in-place CBR tests were conducted during the traffic tests to determine changes in the bearing strength characteristics of both the stabilized-soil layer and the underlying subgrade. The results of the CBR tests are given in table 5. It should be noted that the CBR data indicated for section 3 (untreated soil) were obtained three weeks after construction and immediately before the application of the 40 coverages which resulted in failure (see photograph 12). In sections 1 and 2, CBR data were taken directly in the trafficked paths after the application of 40, 250, 1000, and 2000 coverages. In addition, CBR's were determined between the trafficked paths (not subjected to traffic) at the conclusion of the traffic test.

42. In general, both sections 1 and 2 show a decrease of CBR with depth from the surface of the stabilized-soil layer. As traffic was applied, the CBR's tended to increase at all depth levels within the

Table 5

Results of Field CBR Tests During Traffic with 10,000-lb Single-Wheel Load

Section	No. of Coverages	CBR Pit: Station	CBR Pit: Track	CBR Pit: Depth, in.	Test Results: Water Content %	Test Results: Dry Density lb/cu ft	Test Results: CBR
1 (8% quicklime)	40	0+05	Right	0 (surface of stabilized layer)	18.1	96.1	53
				6	18.0	92.7	34
				12	18.6	90.9	30
				20 (3.5 in. into subgrade)	28.0	93.3	7
	250	0+08	Left	0	16.5	90.5	42
				6	17.5	88.5	34
				12	18.6	89.0	26
				16.5 (surface of subgrade)	30.5	91.3	8
				20.5	29.6	92.2	7
	1000	0+17	Right	0	13.6	93.9	58
				6	17.9	92.8	55
				12	17.9	89.8	31
				16.5	31.1	89.2	6
				20.5	30.6	89.8	5
	2000	0+25	Right	0	12.4	97.9	80
				6	15.9	91.3	55
				12	16.6	86.1	39
				16.5	28.2	93.3	9
				20.5	30.0	91.5	6
	0*	0+25	Between tracks (not trafficked)	0	12.5	90.4	47
				6	15.6	93.0	48
				12	16.7	92.1	41
				16.5	27.7	94.0	10
				20.5	29.2	92.2	7
2 (4% quicklime)	40	0+75	Left	0	19.5	101.6	52
				6	19.0	93.6	34
				12	20.1	92.1	27
				20	28.9	92.4	7
	250	0+72	Left	0	17.5	98.4	62
				6	18.5	93.3	42
				12	20.2	93.0	29
				16.5	29.1	91.8	7
				20.5	30.1	91.3	6
	1000	0+63	Right	0	16.8	101.5	93
				6	18.4	98.2	65
				12	19.4	96.8	44
				16.5	29.8	92.0	9
				20.5	31.5	88.9	5
	2000	0+53	Right	0	14.2	105.2	94
				6	18.1	98.6	72
				12	18.6	96.1	34
				16.5	29.1	92.1	9
				20.5	31.1	89.0	6
	0*	0+53	Between tracks (not trafficked)	0	15.1	99.9	87
				6	19.0	98.5	93
				12	18.7	98.5	67
				16.5	27.1	94.5	12
				20.5	31.4	89.8	5
3** (Untreated)	0	0+85	Between tracks	0 (surface of untreated soil)	15.2	110.7	30
				6	20.5	105.7	9
				12	21.3	104.5	8
				17 (surface of subgrade)	28.9	92.1	5
				21.1	30.4	91.1	5

Note: Water contents are based on total weight of dry solids.
* Tested after 2000 coverages of adjacent tracks.
** Data for section 3 (untreated soil) taken three weeks after construction and immediately prior to application of 40 coverages resulting in failure.

stabilized layer, but less so at the 12-in. depth than at the surface of the stabilized layer. Section 2 (4% quicklime) exhibited higher CBR's than section 1 (8% quicklime) throughout the tests, which is in disagreement with previous laboratory test data (see fig. 4 and table 3). In both sections, however, sufficiently high CBR's were developed and maintained to tolerate the full 2000 coverages of the 10,000-lb single-wheel load without damage. Further, it may be seen that the surface CBR of the subgrade, initially about 4, increased to 7 in both sections during the application of the first 40 coverages (applied one day after construction of the test section). With additional traffic, the surface CBR of the subgrade continued to show an increase, approaching 10 directly under the traffic paths, and somewhat surprisingly, values greater than 10 outside of the traffic paths. At depths of 4 in. below the surface of the subgrade, however, the CBR's were lower and remained relatively stable at about 5 to 7. Examination of the subgrade surface data shows that, adjacent to the stabilized layer, the water contents of the subgrade were generally lower than at the time of construction. However, at a depth of 4 in. into the subgrade the water contents were comparable to the as-constructed water content. It is suggested that treatment of the soil above the subgrade with quicklime influenced the characteristics of the subgrade, and it is probable that the effect was primarily one of extracting water from the adjacent surface of the subgrade for hydration of the lime. The significance of this phenomenon will be discussed later.

Test results with 25,000- and 50,000-lb single-wheel loads

43. As mentioned earlier, this phase of traffic testing, originally unscheduled, was conducted in conjunction with an unrelated WES project. These tests were made nearly three months after construction of the test section, and involved the application of two heavier wheel loads as described in paragraphs 34 and 35. Observations and test data taken during this phase of traffic were limited, by necessity, to avoid interference with the primary test operation. Before traffic was started the test section was fine-bladed to smooth the stabilized-soil surface. About 1 in. of material was removed by the blading operation, resulting in an average stabilized-layer thickness of 15.5 in. A total of 133 coverages was

applied with the 25,000-lb wheel load with no evidence of distress to either section 1 or 2. Similarly, no distress was observed in either section during the application of 100 coverages of the 50,000-lb wheel load. Permanent deformation or rutting of the stabilized layer increased during traffic as shown in fig. 20. The 50,000-lb load resulted in slightly greater deformation, with a maximum of about 0.3 in. occurring in section 1.

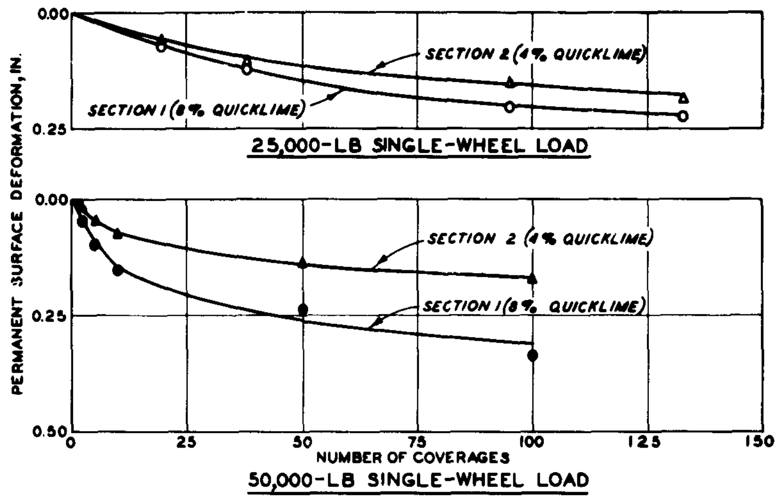


Fig. 20. Surface deformation versus number of coverages (from average traffic path center-line profile data), 25,000- and 50,000-lb single-wheel loads

44. Results of field in-place CBR tests in both sections before and after traffic with the 25,000- and 50,000-lb wheel loads are given in table 6. The before-traffic CBR's of both the stabilized-soil layer and

Table 6

Results of Field CBR Tests During Traffic with 25,000- and 50,000-lb Single-Wheel Loads

		Before Traffic			After Traffic: 133 Coverages 25,000-lb Load			After Traffic: 100 Coverages 50,000-lb Load		
Section	Depth, in.	Water Content %	Dry Density lb/cu ft	CBR	Water Content %	Dry Density lb/cu ft	CBR	Water Content %	Dry Density lb/cu ft	CBR
1 (8% quicklime)	0 (surface of stabilized layer)	10.8	95.3	53	9.9	88.7	45	11.4	95.7	51
	6	13.3	92.4	59	14.5	90.1	45	15.1	89.9	48
	12	14.9	82.9	33	14.9	85.5	32	17.2	87.8	39
	15.4 (surface of subgrade)	27.3	93.0	11	26.8	95.5	12	27.0	95.7	14
	19.4	28.9	92.7	7	28.8	92.6	8	29.3	92.2	8
	25.4	29.1	92.0	7	28.7	92.1	7	29.5	91.5	7
	31.4	30.4	91.2	5	30.0	90.6	6	30.4	89.3	5
2 (4% quicklime)	0	13.2	101.3	103	13.2	96.1	109	12.9	98.0	90
	6	18.2	98.0	110	17.4	95.3	78	17.2	93.3	75
	12	17.7	89.9	60	17.7	89.9	58	18.9	93.6	64
	15.5 (surface of subgrade)	28.1	92.2	9	26.3	97.0	11	26.8	95.8	14
	19.5	28.5	92.3	8	27.0	95.5	9	27.6	93.2	9
	25.5	28.3	92.7	8	28.7	92.9	9	29.4	92.1	8
	31.5	28.7	91.0	7	28.4	93.0	7	28.6	92.9	8

Note: Water contents are based on total weight of dry solids.

the subgrade were only slightly higher than those obtained some weeks before at the conclusion of tests with the 10,000-lb traffic load (table 5). However, the water contents of the stabilized layer were considerably lower than at the end of the 10,000-lb wheel-load test. The effect of traffic with the heavier wheel loads on the stabilized-layer and subgrade strengths is evident from table 6. Although the stabilized soil did not change significantly, the surface of the subgrade increased in bearing strength under the applied traffic, particularly under the 50,000-lb load.

45. Following the application of this traffic without distress, the thickness of the stabilized layer of section 1 was reduced to about 7 in. and additional traffic was applied with the 50,000-lb wheel load. On the first coverage, cracks approximately 3/16 in. wide appeared in the stabilized layer parallel to the wheel path. These cracks increased in width with additional coverages to about 1/2 in. after 20 coverages. At this point surface ruts of about 1/2 to 3/4 in. were observed and the test section was considered failed because of damage to the stabilized layer.

Supplementary Surface Strength Tests

Direct field samples

46. To supplement field in-place CBR tests as a measure of the stabilized-soil surface strengths, several attempts were made to obtain chunk samples for laboratory compressive strength tests. In every instance the samples fractured or simply fell apart because of a lack of cohesion between the treated-soil particles. The addition of the quicklime to the lean clay had resulted in a friable, granular-like material with high bearing strength when compacted but with little resistance to shear when disturbed.

Field-mixed, laboratory-molded samples

47. The difficulty in direct field sampling had been anticipated; therefore, immediately after the field mixing operation, samples of the quicklime-treated soil were taken to the laboratory and specimens were molded with the Harvard miniature apparatus for compressive strength tests. Three different efforts of the 40-lb spring tamper were used in an attempt

to bracket field densities. After compaction the specimens were cured at 100% relative humidity for varying lengths of time and then tested in unconfined compression. Some specimens also were prepared using field-mixed material that was subjected to additional hand-mixing in the laboratory. The results of these tests are summarized in table 7. Material from section 2 (4% quicklime) generally had higher strengths than material from section 1 (8% quicklime). It is particularly significant that compaction at greater efforts resulted in increased densities and vastly improved

Table 7

Results of Unconfined Compression Tests on Specimens Prepared from Field-Mixed Material

Section	Compaction Effort		As Molded			After Curing at 100% Relative Humidity as Indicated			
	No. of Layers	Tamps per Layer	Water Content %	Dry Density lb/cu ft	Unconfined Compressive Strength psi	No. of Days	Water Content %	Dry Density lb/cu ft	Unconfined Compressive Strength psi
1 (8% quicklime)	5	10	18.0	86.2	39	1	16.6	88.7	49
						3	16.8	90.3	57
						7	15.4	89.3	74
						14	16.7	89.1	81
	5	25	18.0	88.7	48	1	16.6	91.0	69
						3	16.6	91.6	85
						7	16.2	93.4	92
						14	16.4	91.4	89
	10	25	17.5	90.7	--	1	16.4	92.4	131
						3	16.2	93.1	145
						7	16.3	92.5	148
						14	--	--	--
2 (4% quicklime)	5	10	20.1	91.4	48	1	19.8	93.0	68
						3	19.1	93.8	99
						7	18.5	94.8	119
						14	18.0	92.6	120
	5	25	20.5	94.1	46	1	19.8	96.4	89
						3	19.0	96.7	103
						7	18.9	96.5	135
						14	18.4	96.7	152
	10	25	20.2	96.8	--	1	19.6	96.7	125
						3	19.4	97.4	158
						7	18.7	99.8	220
						14	--	--	--
1*	5	10	18.3	91.0	44	1	17.8	92.4	71
						3	--	--	--
						7	--	--	--
						14	--	--	--
2*	5	10	20.4	96.4	54	1	19.6	96.2	[illegible]
						3	--	--	--
						7	--	--	--
						14	--	--	--

Note: Specimens were compacted using Harvard miniature compaction apparatus equipped with 40-lb spring tamper.
Water contents are based on total weight of dry solids.
* Specimens were compacted after additional 2- to 3-min hand-mixing in laboratory.

strengths after curing. However, the compacted densities and strengths appear to be somewhat lower than might have been expected from previous laboratory studies. This is believed to be a result of the lapse of time between sampling of the treated material in the field and compacting in the laboratory. The studies referred to in paragraph 19 showed that a delay of as little as 1/2 hr between the mixing and compacting operations resulted in 4 to 6 lb per cu ft lower densities and 30 to 50% lower strengths. Of further interest are the results obtained with additional hand-mixing in the laboratory of the field-mixed material. The compacted densities and the strengths after one-day curing time were considerably improved by further mixing, emphasizing the importance of adequate mixing for effective stabilization.

PART IV: ANALYSIS AND DISCUSSION

Traffic Tests

Surface behavior

48. Deformation. During the traffic tests with the 10,000-lb wheel load, the permanent deformation or surface rutting of the stabilized-soil sections was sufficiently small (figs. 16 and 17) that no damage resulted to the stabilized layer, nor was traffic impeded. Although slight cracking of the stabilized-soil surfaces was evident, examination showed the cracks to be less than 1/2 in. deep; these cracks probably resulted from drying of the surface since they appeared in untrafficked areas as well as in the traffic paths. It is of interest in this regard to note that the only area showing no signs of cracking was that beneath the Fiberglas membrane surfacing, even though the degree of consolidation by traffic there was the same as in the rest of the test lane. Similarly, later traffic of the 25,000- and 50,000-lb wheel loads did not result in significant rutting or crack formation. After reduction of the thickness of the stabilized layer (section 1) to 7 in., 20 coverages of the 50,000-lb wheel load resulted in surface ruts 1/2 to 3/4 in. deep and cracks sufficiently wide to cause the section to be considered failed. Inspection of the underlying subgrade showed that it was being displaced under the load, and was approaching failure in shear.

49. Abrasion. The most severe damage to the stabilized layer resulted from raveling and abrading of the surface under the action of the applied traffic. Based on the abraded material collected (fig. 19), approximately 50% of the total loosened material was finer than the No. 200 sieve, and under high-speed traffic this would probably have resulted in a major dust problem with its attendant hazards. Section 1 (8% quicklime) abraded nearly twice as severely as section 2, and in neither section was abrasion reduced by the commercial road oil treatment. Thus, it appears that some form of supplementary surfacing, such as a bituminous treatment or a plastic membrane, is essential to provide a satisfactory dustproof condition for quicklime-stabilized soil. Such a surface would also serve both as a moisture barrier to prevent drying of the stabilized soil while

curing and as a seal against the ingress of moisture from above during periods of inclement weather.

Traffic data

50. The primary objective of this investigation was to determine the ability of quicklime to stabilize a moderately weak soil sufficiently to support traffic for emergency military road and airfield operations. Since an initial CBR of 4 represents the weakest soil condition that is considered feasible to stabilize for such operations, it was desired to test the stabilized layer overlying a 4-CBR subgrade. Failure to satisfy the minimum traffic requirement, which for this situation is represented by 2000 coverages of a 10,000-lb single-wheel load, may result from either (a) inadequate strength development in the stabilized layer to resist stresses of the applied load, or (b) insufficient thickness of the stabilized layer to protect the underlying weak subgrade. If it is assumed that a stabilized layer is sufficiently well compacted during construction to prevent excessive detrimental consolidation of the layer by traffic, any permanent surface deformation must be a result of subgrade settlement. Further, the elastic characteristics of the stabilized-soil layer will determine the extent to which the layer can sustain deformation or deflection under repeated loading without cracking or losing its integrity as a surface. In the absence of significant flexural strength of the stabilized layer, the amount of deflection and permanent settlement of the subgrade depends upon its bearing capacity and the thickness of overlying protective material.

51. The quicklime-stabilized layers in this study were constructed to a thickness of 16.5 in., which is the flexible pavement design thickness for 2000 coverages of a 10,000-lb single-wheel load, 100-psi tire pressure, on a 4-CBR subgrade.* A total of 2000 coverages of the test vehicle was applied without any observed distress of the stabilized layer. Further, it was obvious from the exceedingly low deflection measurements and the slow rate at which deformation was increasing that this traffic could have

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* Initial design from flexible pavement curves specified 16.0-in. thickness based on 70-psi tire pressure. The thickness actually obtained was fortuitously the exact requirement for 100-psi tire pressure, which was employed after 318 coverages of traffic had been applied. Since the majority of traffic was applied with the 100-psi tires, and no effect was apparent due to the change, only this tire pressure will be considered.

continued practically indefinitely. Although the satisfactory performance of the stabilized-soil layers verified the ability of quicklime to develop more than adequate strength to satisfy the traffic requirements, the only conclusion that may be made in regard to deformation is that at least 0.3 in. can be tolerated by the stabilized layer without damage. The reason for the low observed deformations is apparent upon inspection of the subgrade CBR data (table 5), which show a significant increase from the initial 4 CBR to values of at least 7 CBR shortly after placement of the quicklime-treated soil on the subgrade. By the time traffic with the 25,000- and 50,000-lb wheel loads was applied (on a 15.5-in.-thick stabilized layer), the subgrade strengths had increased to even greater values (table 6) and the deflections and deformations still were not sufficient to distress the stabilized layer. After reduction of the thickness of the stabilized layer to about 7 in., a failure resulted after 20 coverages of the 50,000-lb wheel load, with measured deformations ranging from 1/2 to 3/4 in. Thus, about 1/2 in. is believed to be a reasonable estimate for the maximum allowable deformation that can be tolerated by a quicklime-stabilized layer having the characteristics and properties obtained in this test.

52. The application of 2000 coverages of the 10,000-lb wheel load resulted in only about one-half of the tolerable deformation, due primarily to an immediate increase in the subgrade CBR which was believed to be an effect of the contact with the quicklime-treated soil. Thus, it is apparent that advantage can be taken of the improved subgrade strength in the form of a reduction in thickness of the stabilized layer. From the subgrade data in table 5, it is conservatively estimated that an increase in CBR at the surface of the subgrade from an initially constructed 4 to a value of about 7 was achieved. Further, the data indicate that the CBR increases were of sufficient depth that the subgrade surface bearing value was the critical one for design purposes. From existing flexible pavement design curves, it is determined that a 12-in. thickness of construction is required over a 7-CBR subgrade to support 2000 coverages of a 10,000-lb single-wheel load with 100-psi tire pressure. Thus, a thickness reduction of 4.5 in. is indicated from the design based on the 4-CBR initial subgrade condition. This is a significant reduction and extremely advantageous in

terms of both reduced construction effort and reduced total quantity of stabilizing material required per unit area of stabilization.

Stabilized-Layer Strength Considerations

53. Based on the traffic test results, it may be concluded that the quicklime-stabilized lean clay developed adequate strength, and was sufficiently well constructed and compacted to support the intended traffic without failure according to established criteria. The improvement was realized well within the maximum one-day curing period, and is particularly impressive in view of the inability of the untreated soil (section 3), placed at the same initial water content, to support more than one coverage without immobilization. In terms of bearing strength, the stabilization with 4% quicklime w.s somewhat better than that with the 8% treatment, although the reverse was expected originally on the basis of preliminary laboratory tests. This difference, resulting most likely from less effective mixing in the case of the 8% treatment, was reflected by slightly better performance in the traffic tests of section 2 as compared to section 1. Since no failure occurred in the stabilized layers as a result of inadequate strengths, the only conclusion that may be made is that the lowest surface bearing strength measured during traffic, or about 40 CBR (from table 5), was more than enough to resist stresses of the applied 10,000-lb wheel load.

54. In terms of unconfined compressive strengths, the only data available were from the laboratory-compacted field-mixed material (table 7). From the densities obtained, it is not unreasonable to assume that the specimens compacted at the higher effort were more nearly representative of the top lift of the field-constructed stabilized layers than those compacted at the lower efforts. Considering only the strengths after one-day curing, it is evident that 125-psi unconfined compressive strength was at least sufficient to withstand the applied traffic load, and that probably some value less than this would have sufficed. Until evidence is obtained to the contrary, a laboratory unconfined compressive strength criteria of 100 psi is considered reasonable as an indication of stabilizer effectiveness in preliminary testing.

Evaluation of Mixing and Construction Techniques

55. The successful stabilization achieved with quicklime was, to a large extent, the result of good construction technique. Of primary importance was the placement of the stabilized layer in shallow lifts which permitted effective compaction to be accomplished. Within the limits of the bearing capacity of the underlying material, each lift was compacted to a maximum density by increasing the compaction load for the successive lifts. Although a density gradient existed in the 16.5-in. layer, the compaction achieved in this manner was sufficient to enable the treated material to resist further consolidation at any given depth below the surface by the subsequently applied traffic load. This technique of construction, although successfully employed for this particular investigation, would be undesirable for an actual military field stabilization situation. As originally conceived, a stabilization capability is desired that would involve only a single-lift, in-place mixing and compacting operation. This problem can be of considerable concern where fairly large thicknesses are involved, since previous experience in soil-stabilization construction has indicated that lifts thicker than about 6 in. do not receive adequate compaction. Barring the development of a unique stabilizing material that is effective regardless of density, it may be necessary to consider multiple-lift construction with the attendant disadvantage of added construction effort.

56. Effectiveness of mixing also is an important factor in soil stabilization. The technique used in this investigation involved initial blending of the soil and quicklime with a common disk harrow, followed by three coverages with a standard Pulvi-mixer. As shown previously in fig. 11, a definite difference in the response to mixing was observed between the 8 and 4% treated soil. The 4% admixture appeared visually to be very well mixed, and relatively free of lumps of unmixed soil. With the 8% treatment, however, soil balls were formed that became coated with a thick layer of lime and resisted further breakdown by mixing. Surprisingly, later excavations for CBR pits revealed a rather intimately mixed material for both admixtures, with no particular evidence of untreated soil lumps even in the 8% treated layer. This might possibly be attributed to a

combination of the action of the lime tending to break down the wet clay lumps and the forced contact of the lime and unmixed soil in the compaction operation. Although the mixing was considered to be reasonably effective, additional hand-mixing of the sampled field-mixed material resulted in an improved stabilization (table 7). It is believed that construction of shallow lifts also was beneficial to mixing, but as in the case of compaction, this type of construction does not represent the ideal technique (a single-pass, single-lift operation). This is an equipment limitation problem and can be solved only by the development of an improved mixing capability.

Evaluation of Quicklime as a Military Stabilizer

57. The results of this study have demonstrated that quicklime, applied to a weak, lean clay soil in a quantity of as little as 4% by soil weight, is able to satisfy the strength and traffic performance requirements demanded of a stabilizer for emergency military road and airfield operations. The field investigation was limited, however, in that no study was made to determine the ability of the quicklime-stabilized soil to maintain its effectiveness when subjected to weathering effects, particularly rainfall. The speculation of possible deterioration of the stabilized soil resulting from exposure to the elements becomes significant only if it is assumed that no supplementary protective surfacing is to be provided. However, this investigation indicated the necessity for some form of wearing surface to prevent excessive raveling and abrading of the exposed stabilized material. A form of surfacing, such as the bituminous treatment used in the test, would solve both the dust and the exposure problems. On this basis, quicklime stabilization can be considered satisfactory only if a supplementary protective surface is provided. From the standpoint of military application, this requirement is not particularly desirable since it creates the problem of increased logistic and construction effort. It is, however, possible that an improvement in stabilization with quicklime could be achieved by chemical modification to the extent, perhaps, of eliminating the need for a protective surfacing.

58. A second limitation of this investigation is that the

effectiveness of quicklime was established for only one soil type. Because the stabilizing ability of quicklime may be dependent upon soil type, or on specific soil composition or chemical characteristics, it is not possible at this stage of investigation to draw conclusions concerning its broad applicability. Therefore, additional investigation to study the effectiveness of stabilization with quicklime in various soils appears to be warranted.

59. During the preliminary laboratory investigation with quicklime, it was determined that the strength of the stabilized soil was dependent upon the water content of the soil, and that at a water content below some certain critical value an expansion in volume and complete disintegration of the compacted specimens occurred. Further, an upper water content limit exists above which the effectiveness of stabilization is considerably reduced. For the soil used in this study the effective water content range was rather limited. The possible significance of this limitation was not apparent in this investigation, since the test soil water content resulting in the minimum anticipated initial soil strength condition of 4 CBR for category 2 was within the acceptable water content range. This might not be the case with every soil type, however, since it is conceivable that an initial category 2 water content condition may exist that falls outside the limits of effective stabilization. Even for the particular soil employed in this study, an initial condition of, say, 10 CBR could exist that still would demand improvement in strength by stabilization to satisfy the category 2 traffic requirements. In this case the soil would be at a water content of about 19%, which according to this study is too low for adequate quicklime stabilization. Although water could be added to the soil-stabilizer system in such situations, this would involve an increased effort in construction which is not desirable. The full importance of this limitation must be established and possible corrective measures explored before quicklime can be considered a satisfactory soil-stabilizing material for military use.

60. A primary benefit of quicklime, as indicated in this investigation, was its apparent ability to influence the underlying subgrade such that a higher bearing capacity resulted therein. The effect of improved subgrade strength represents an advantage by requiring less thickness of

overlying material for protection. This unexpected phenomenon requires further investigation and confirmation.

61. From the standpoint of both cost and availability, stabilization with quicklime is favorable. Stabilization of a mile of roadway 13 ft wide to a depth of 12 in. would require about 150 tons of quicklime (assuming a 4% treatment) at a cost of about $4500 exclusive of shipping and construction costs. Further, quicklime is relatively abundant and available in most areas of the world. Although quicklime does present some hazard in handling and storage because of its reactivity, this problem can be minimized by proper safety measures in handling and the development of suitable containers.

PART V: CONCLUSIONS AND RECOMMENDATIONS

Conclusions

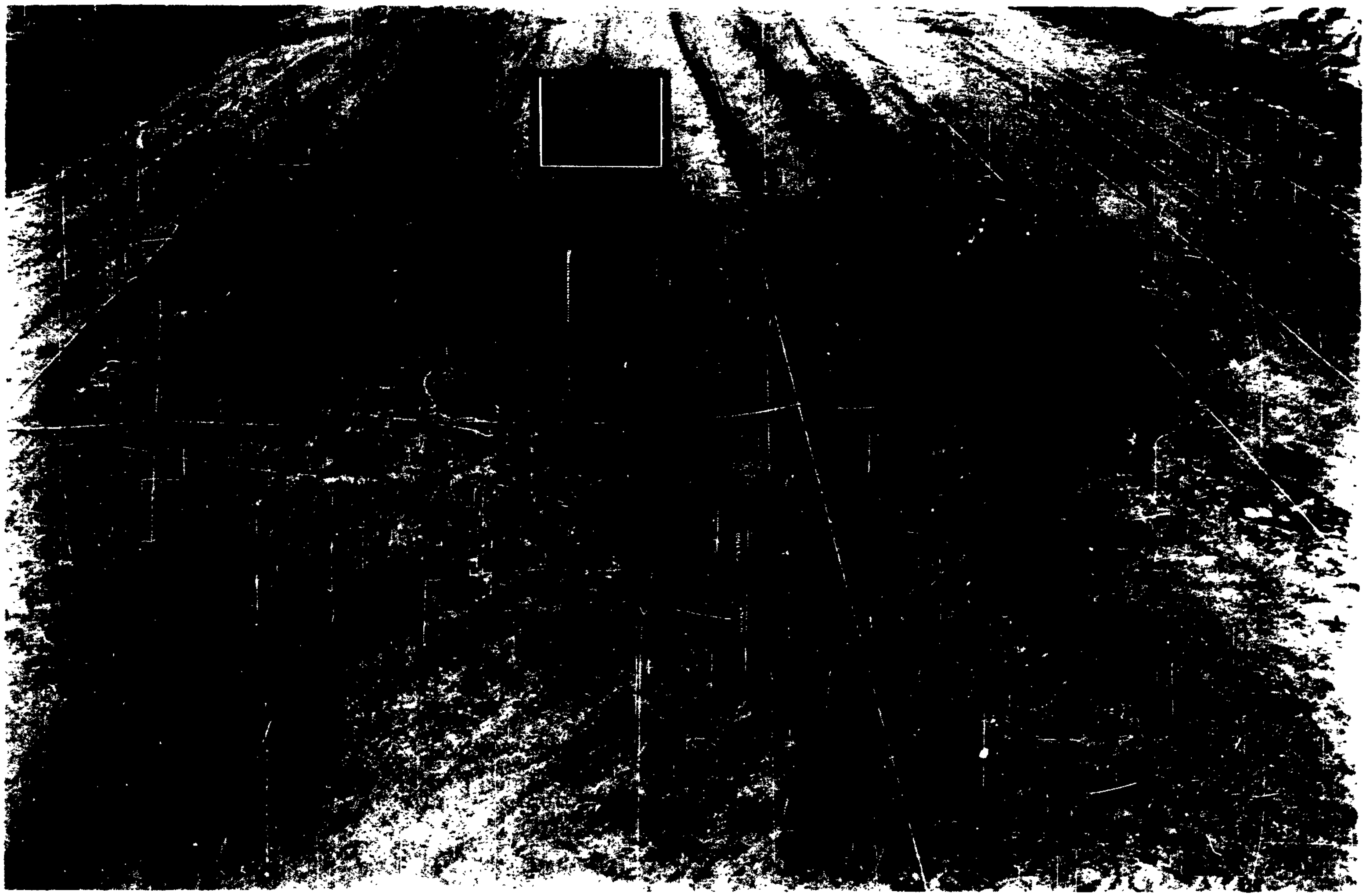
62. On the basis of this investigation, it is concluded that:

- a. The addition of as little as 4% quicklime by soil weight is capable of increasing the unconfined compressive strength of a particular lean clay soil (Vicksburg loess) from an initial 20 psi to over 100 psi, and the bearing capacity from a CBR of 4 to over 50, within a 24-hr curing period.
- b. Although in the field the strengths of both 4 and 8% quicklime-stabilized soil surfaces constructed over a weak subgrade proved to be more than adequate to meet minimum traffic requirements for emergency military road and airfield operations, the actual suitability of quicklime may be questionable because of a significant and perhaps critical dependency of its effectiveness on initial soil water content.
- c. An improvement in bearing capacity appears to take place in a weak subgrade underlying a quicklime-treated soil layer, probably due to extraction of water from the subgrade for hydration of the lime; this is beneficial in terms of reducing the layer thickness required to accomplish a specific traffic objective.
- d. An exposed quicklime-soil surface is susceptible to considerable raveling and abrading from traffic. Since this condition was not alleviated by a penetration treatment with a commercial road oil, a need for some type of supplementary protective wearing surface is implied.

Recommendations

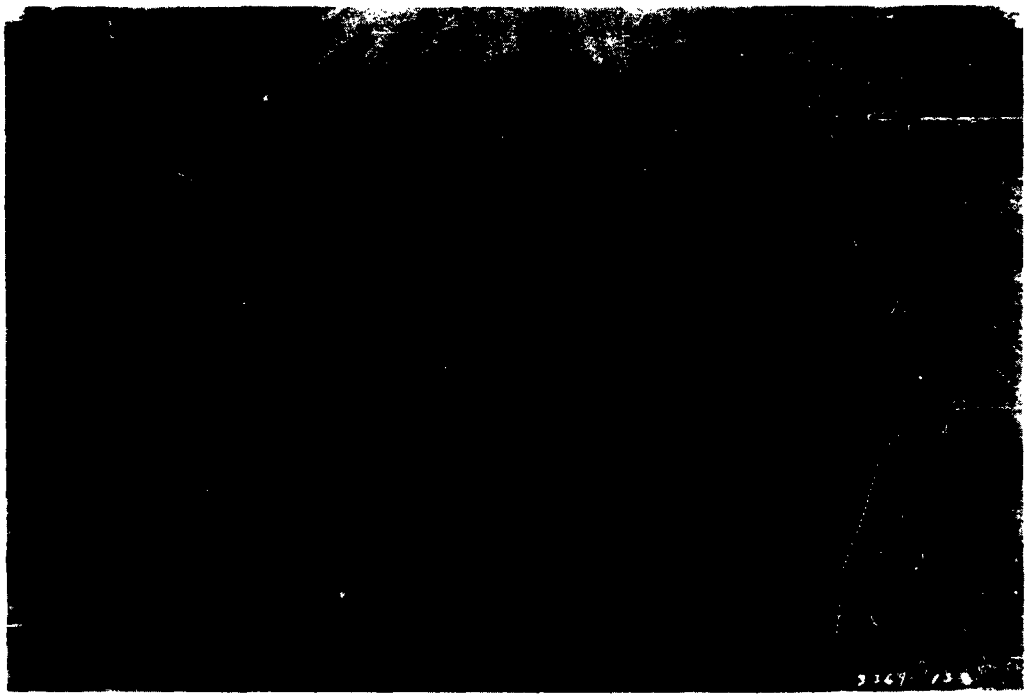
63. The following recommendations are made:

- a. Continue laboratory research and, if warranted, conduct additional field investigations to determine more fully the ability of quicklime to satisfy requirements for a soil stabilizer for use in construction of emergency military roads and airfields.
- b. Explore the possibility of improving quicklime stabilization by chemical modification (i.e. by use of supplementary secondary additives) in an attempt to overcome certain limitations and undesirable characteristics of quicklime brought to light in this investigation.



Photograph 1. Failure of untreated soil section after 1 coverage with 10,000-lb single-wheel load

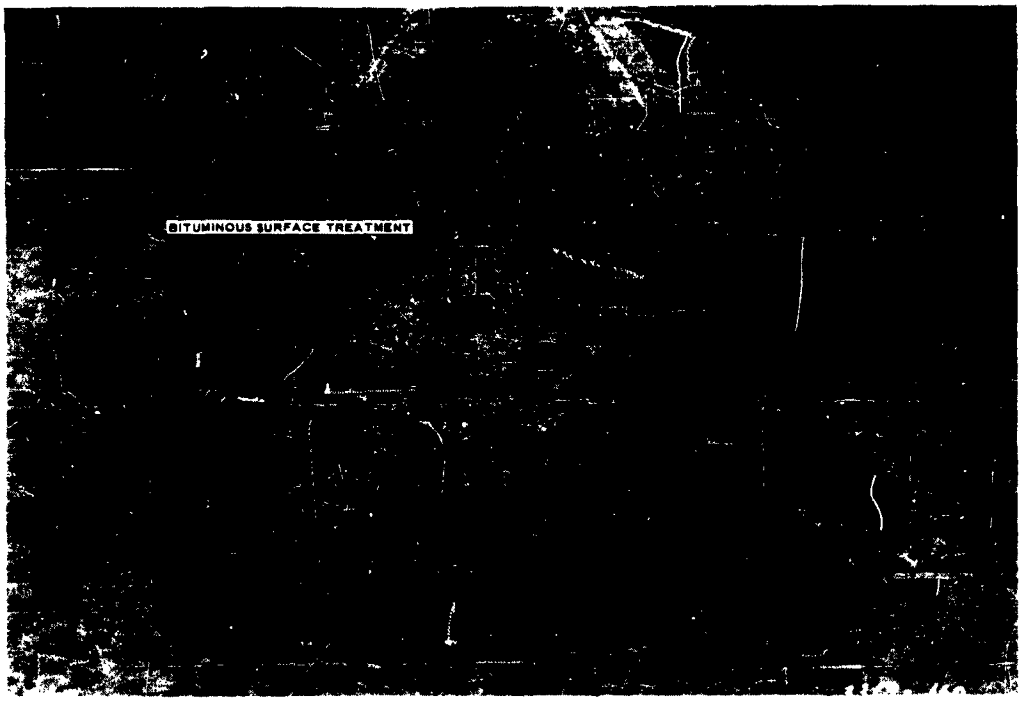
Photograph 2. Section 1 prior to traffic



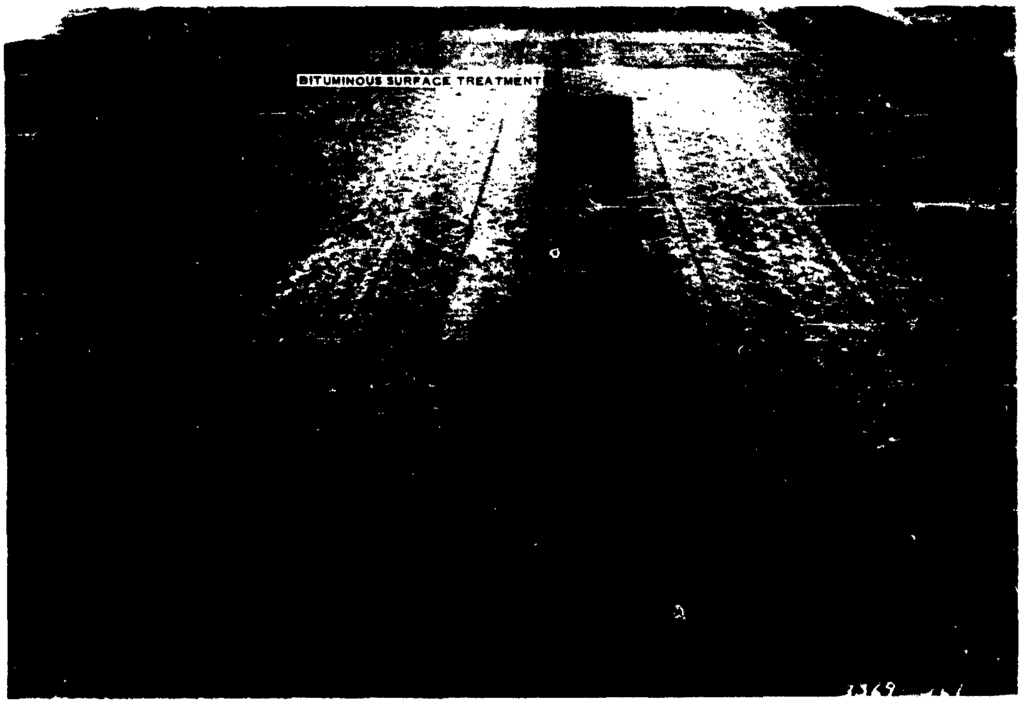
Photograph 3. Section 2 prior to traffic

Photograph 4. Section 1 after 40 coverages of 10,000-lb load

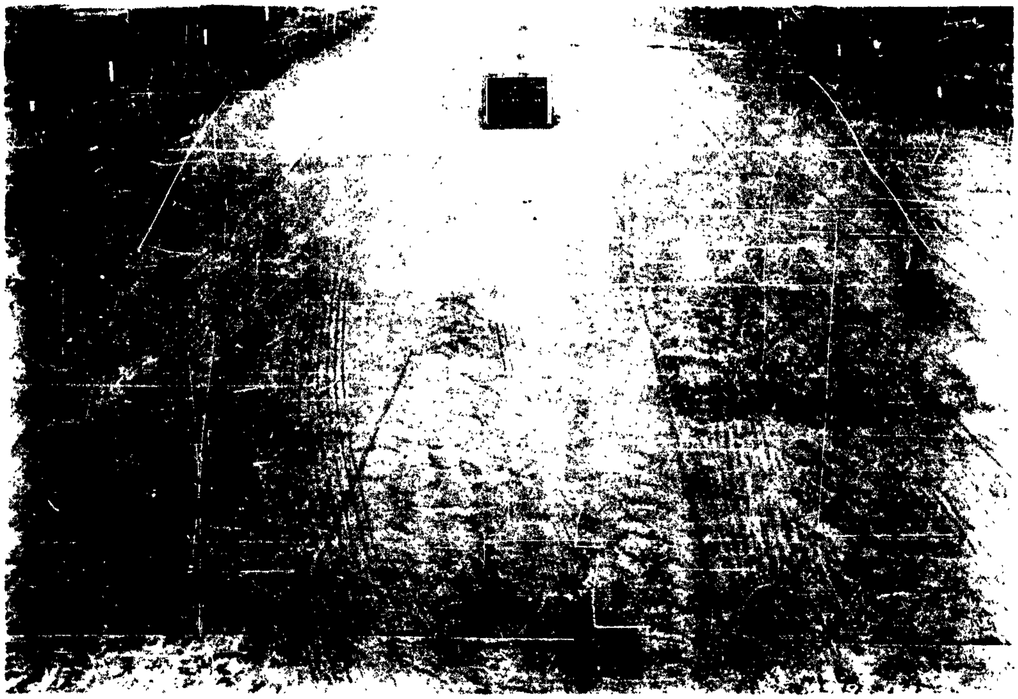
Photograph 5. Section 2 after 40 coverages of 10,000-lb load



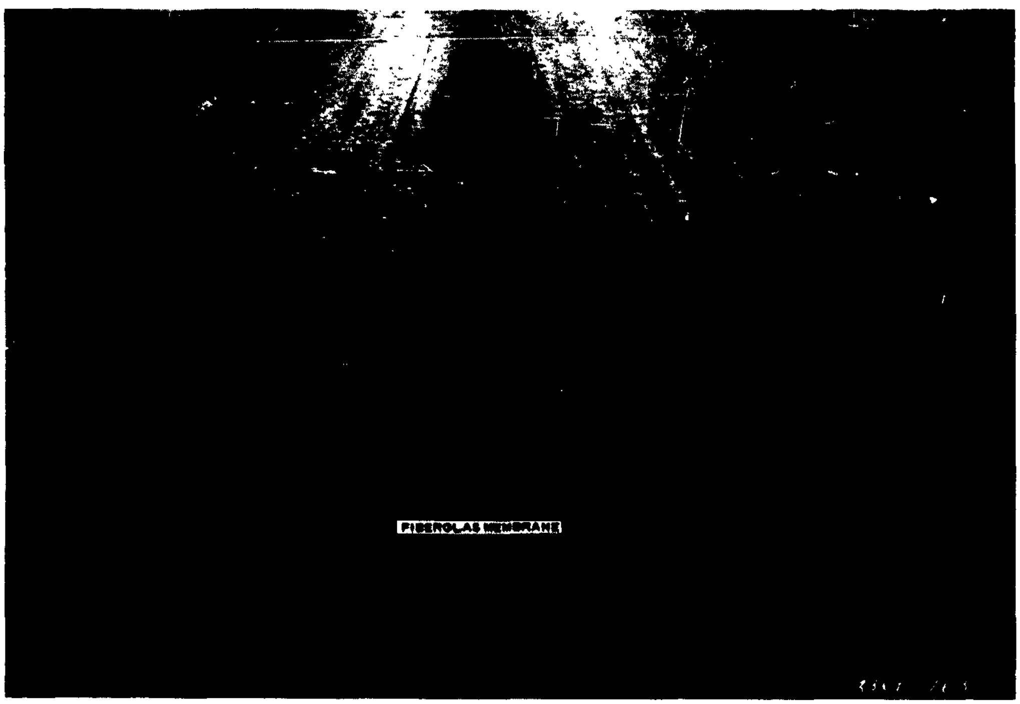
Photograph 6. Section 1 after 250 coverages of 10,000-lb load



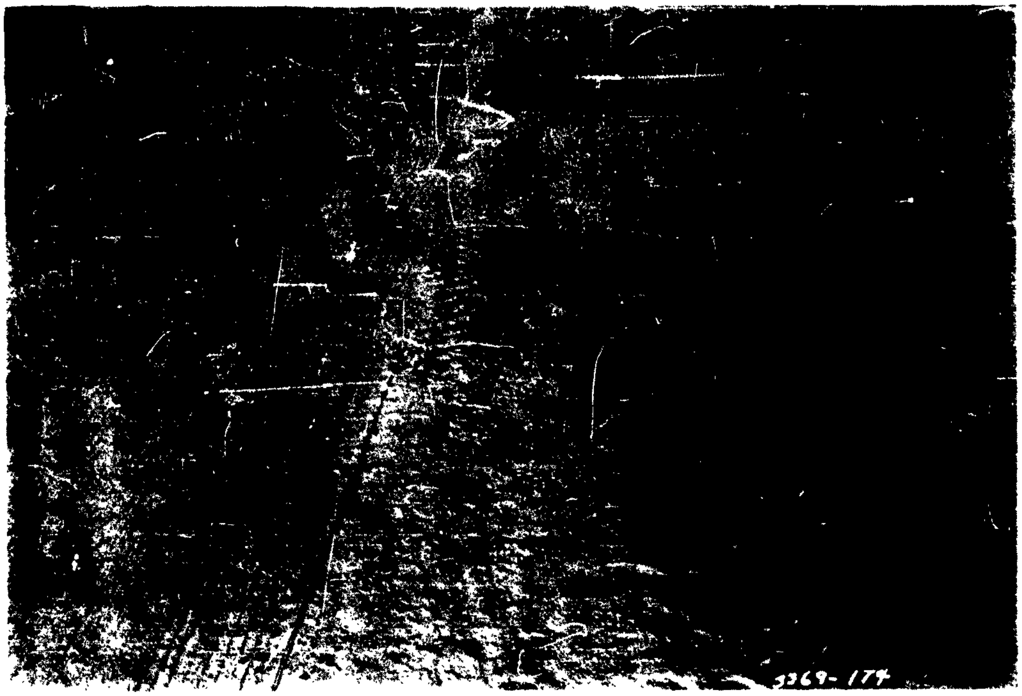
Photograph 7. Section 2 after 250 coverages of 10,000-lb load



Photograph 8. Section 1 after 1000 coverages of 10,000-lb load

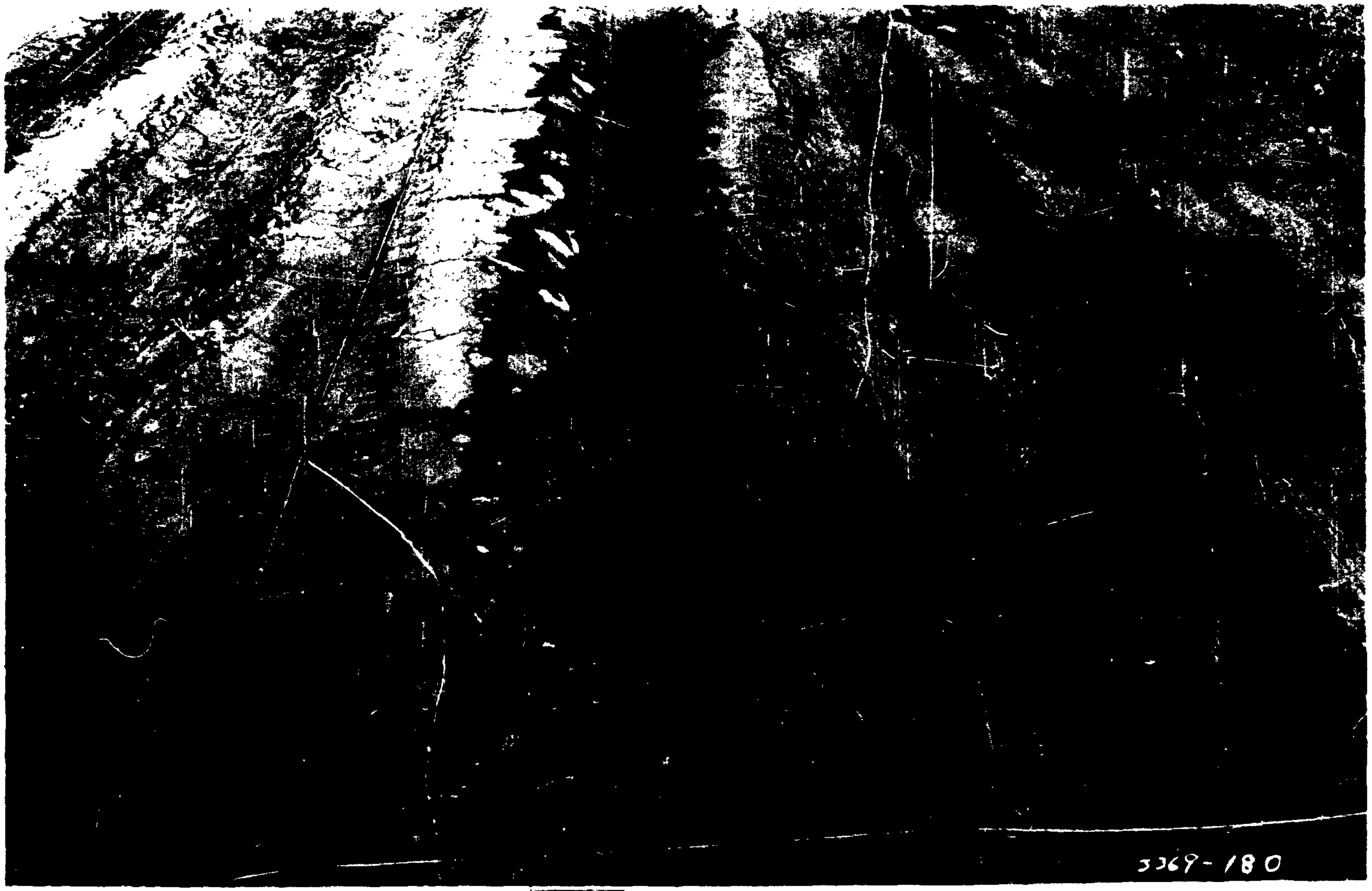


Photograph 9. Section 2 after 1000 coverages of 10,000-lb load



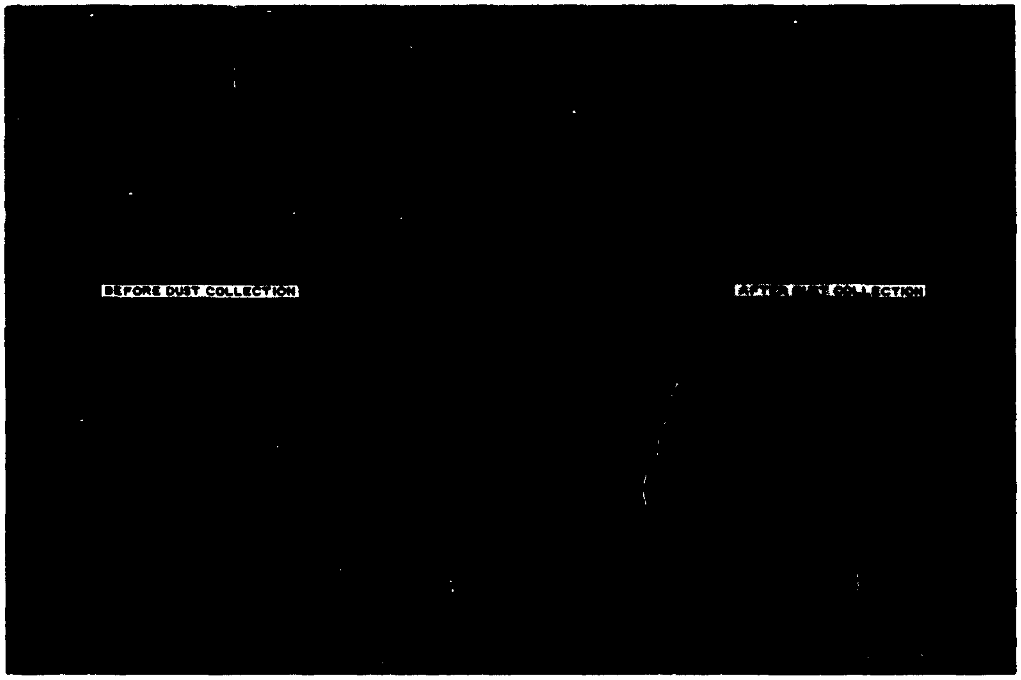
Photograph 10. Section 1 after 2000 coverages of 10,000-lb load

Photograph 11. Section 2 after 2000 coverages of 10,000-lb load

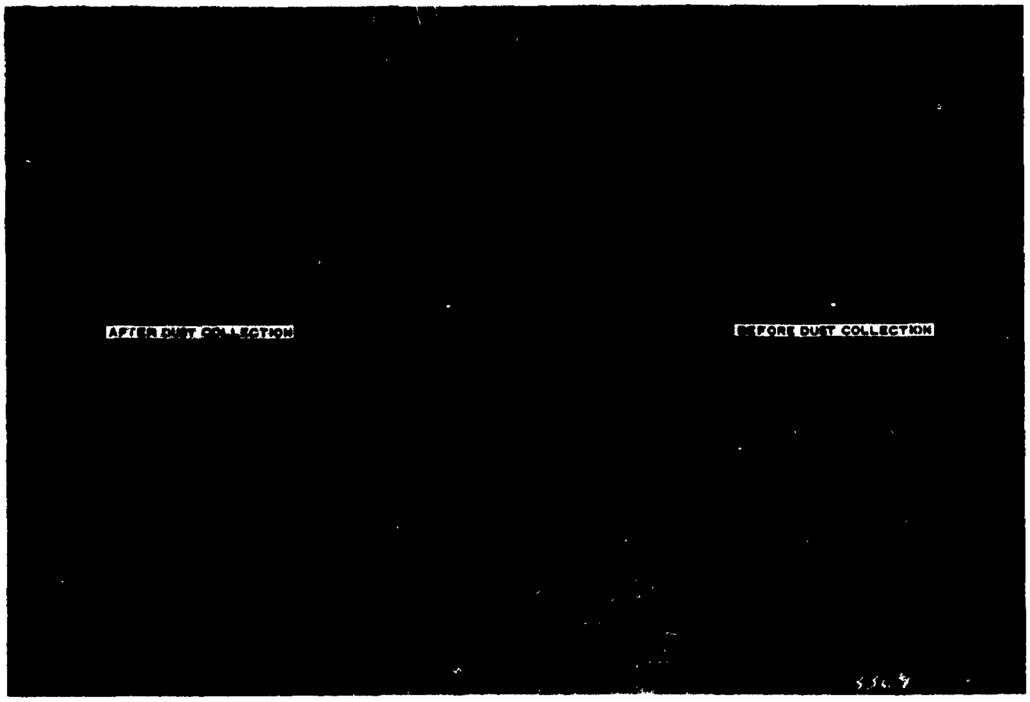


Photograph 12. Appearance of section 3 (untreated soil) after 40 coverages by 10,000-lb test cart. Test was conducted about three weeks after initial placement of this section

Photograph 13. Section 1 without road oil after 100 coverages of 10,000-lb load



Photograph 14. Section 1 with road oil after 100 coverages of 10,000-lb load

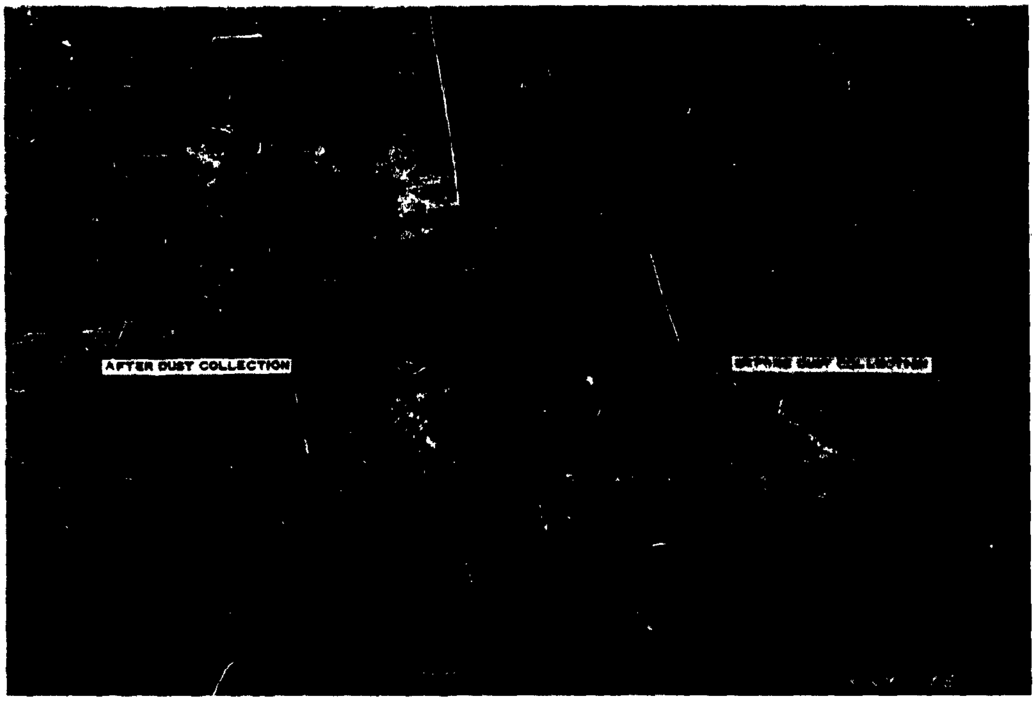


Photograph 15. Section 2 without road oil after 100 coverages of 10,000-lb load

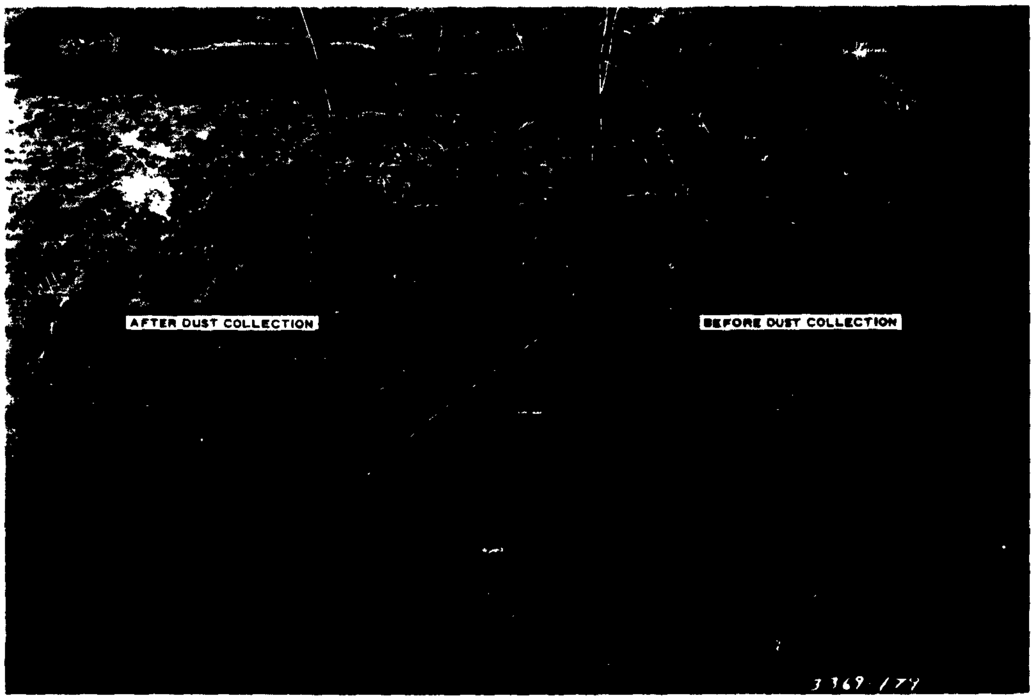
Photograph 16. Section 2 with road oil after 100 coverages of 10,000-lb load

Photograph 17. Section 1 without road oil after 2000 coverages of 10,000-lb load

Photograph 18. Section 1 with road oil after 2000 coverages of 10,000-lb load



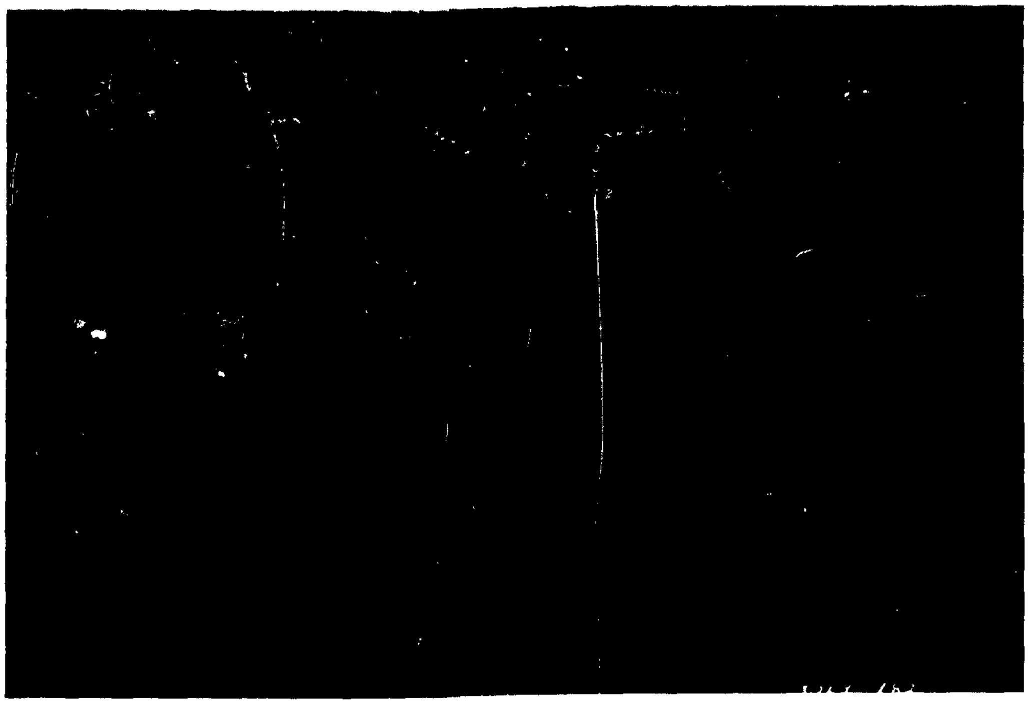
Photograph 19. Section 2 without road oil after 2000 coverages of 10,000-lb load



Photograph 20. Section 2 with road oil after 2000 coverages of 10,000-lb load

Photograph 21. Condition of plastic membrane protective surface after 2000 coverages of 10,000-lb load

Photograph 22. Comparison of stabilized-soil surface protected with plastic membrane after removal of membrane (left) with unprotected surface (right) after 2000 coverages of 10,000-lb load



Photograph 23. Condition of bituminous surface treatment after 2000 coverages of 10,000-lb load compared with unprotected surface on left

U. S. Army Engineer Waterways Experiment Station, CE, Vicksburg, Miss. SOIL STABILIZATION; INVESTIGATIONS OF QUICKLIME AS A STABILIZING MATERIAL, by G. R. Kozan and W. B. Fenwick. March 1962, vii, 47 pp - illus - tables. (Technical Report No. 3-455, Report 5)

Unclassified report

Laboratory tests showed that as little as 4% quicklime by soil weight increased the unconfined compressive strength of a lean clay soil from 20 to 100+ psi, and its CBR from 4 to 50+ within 24 hr. However, the effectiveness of quicklime appears to be dependent upon initial soil water content, and particularly in absence of sufficient water for hydration, quicklime actually may be detrimental to soil. In the field, the lean clay soil at 4 CBR was treated with both 4 and 8% quicklime concentrations and compacted in 4-in. layers to a 16-in. thickness overlying a 4-CBR subgrade. Under traffic the quicklime-stabilized soil layer was sufficiently strong and well compacted to withstand minimum requirements for emergency military roads and airfields. However, the exposed quicklime-soil surface was not adequately resistant to abrasion by traffic, nor was abrasion lessened by application of a commercial road oil. Further investigations of improving quicklime stabilization by chemical modification or use of secondary additives are recommended.

UNCLASSIFIED

1. Soils

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